TECHNICAL NOTES

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

No. 247

THE DRAG OF AIRSHIPS

By Lieut. Clinton H. Havill, U.S.N.

Washington
September, 1926

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

TECHNICAL NOTE NO. 347.

THE DRAG OF AIRSHIPS.

By Clinton H. Havill.

PART I

Summary

In order to begin research on the drag of airships it was first necessary to make a logical digest of the reported past performances and data given on deceleration tests for a large number of airships. That these data may become available for airship designers in a compact form is the purpose of this report, as well as to serve as the basis on which the author is continuing his researches, which will be given later in Part II (Technical Note No. 248).

This digest as given here in Part I was begun in September, 1923, and worked on intermittently until December, 1925.

The outstanding results are as follows:

1. In general, the maximum speed of most airships was reported about 5 per cent higher than obtained in this report.

2. Total maximum horsepower was reported in many cases higher and in a few cases lower, than obtained in this report.

3. Propulsive coefficients at maximum speeds are in general lower than the reported values. Coefficient "C" is con-

stant and the propeller efficiency "E" is reduced as at maximum speed that the propulsive coefficient "K" falls off.

4. It was further noted that several ships of widely different designs had nearly the same drag coefficient for the whole ship. However, this is looked upon as a coincidence in the cases where the type of hull, cars, and surfaces differed widely.

5. That in general an idling propeller was found to have about fifteen square feet area of drag while a stopped propeller had about six square feet area of drag. This was found by working out the area of drag from the ship's performance and comparing it with the area of drag as obtained on the deceleration test with either stopped or idling propellers as the case was reported. In some cases this difference of area worked out to be 8 or 9 square feet per propeller, but with certain types of engines it is possible that all engines were not stopped but that one or two were left idling during the deceleration tests.

Applied values of principle data and results are given in Table I and Fig. 3.

Introduction

At the beginning of the research - "The Drag of Airships" - it was immediately discovered that there was much conflicting data on record concerning any given particular ship. Deceleration tests had been performed on some ships, yet the results of

these tests did not always agree with that held on exactly similar ships. The reported maximum speeds, propeller efficiencies, and maximum horsepower would give a drag coefficient that differed widely from that reported or found on the deceleration tests. Or, again, using the drag coefficient found on deceleration tests together with the maximum horsepower and reported maximum speed would in many cases give a propeller efficiency that was highly improbable.

A digest by Lipka's empirical method of digesting inconsistent data was applied to the following quantities: maximum speed, maximum total horsepower, propulsive coefficient at maximum speed, propeller efficiency at maximum speed, area of drag (power on), and drag coefficient for the whole ship. This was done not only for the data concerning each individual ship but taking into account the relation between ships on the two quantities of drag coefficient and propeller efficiency upon which many quantities depended. The method of how this relation was obtained is explained fully in the explanation of Lipka's method as given later in this report.

The reasons for undertaking this problem was primarily to digest the results already obtained in flight on full-sized ships so that the results could be used for further research work as will be given later in Part II (Technical Note No. 248).

The scope of the work extends over nearly all the Zeppelin ships together with five types of nonrigid airships. The method

used is Lipka's empirical method of digesting inconsistent data and is explained as follows:

The method chosen for the digestion of inconsistent data is the invention of the late Professor Joseph Lipka. It is described as the "method of selected points" in Professor Lipka's book "Graphical and Mechanical Computation." This method is frankly empirical, and has not the rigid mathematical justification of the method of least squares, but it is far less laborious, and has the great advantage for the present problem that data which is known to be especially reliable can arbitrarily be given more weight than other data of less certain accuracy.

Lipka's method does not always give results converging to consistency. If the sum of the errors is very large, each approximation shows increasing divergence from consistent values, showing that the data is too unreliable to be considered.

Explanation of Lipka's Empirical Method
for the Digest of Inconsistent Data

Lipka's empirical method of making inconsistent data consistent with the theoretical mathematical relation that exists.

As a simple example, Case 1:

A rectangle actually exists as in Fig. 1.

An observer measures side "a" and reports 5.1

" " " " "b" " " 3.9

" " " area "A" " " 20.11

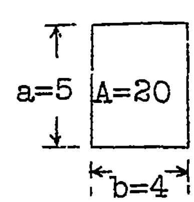

Fig.1

These reported values have been measured perhaps by different observers at different times and the accuracy of their data is not known as yet; for the purpose of research, let us therefore assume that $ab = A$ must hold true to four (4) significant figures. This is analogous to the reported data concerning a single airship. Yet with airships, the reported values of drag coefficient, horsepower, maximum speed, propeller efficiencies at maximum speed, and propulsive coefficient are interconnected by mathematical relations and would only serve to complicate the explanation of the method. The relation between different ships will be later explained analogous to using two rectangles.

Reported values	
	: Assume A and b correct, then $a = \frac{A}{b} = 5.146$
$a = 5.1$	
$b = 3.9$	: Assume A and a correct, then $b = \frac{A}{a} = 3.943$
$A = 20.11$	: Assume a and b correct, then $A = ab = 5.1 \times 3.9 = 19.89$

These values of a, b, and A are the 1st approximation:

1st approximation:	
	Reported a = 5.1
$a = 5.146$	1st approx. a = 5.146
$b = 3.943$	2:10.246
$A = 19.89$	5.123 = 1st mean value of a
	Reported b = 3.90
	1st approx. b = 3.943
	2: 7.843
	3.922 = 1st mean value of b
	Reported A = 20.11
	1st approx. A = 19.89
	2:40.00
	20.00 = 1st mean value of A

Test for consistency $ab = 5.123 \times 3.922 = 20.092 = A$, calculated value.

1st mean value of A . . . . $= \frac{20.00}{.092}$

Consistent to only three significant figures.

Now consider these mean values as new reported values and continue the process to the second approximation.

Similar to method of first approximation:

$$a = \frac{\text{1st mean } A}{\text{1st mean } b} = \frac{20.00}{3.922} = a, \text{ 2d approx.} = 5.099$$

$$b = \frac{\text{1st mean } A}{\text{1st mean } a} = \frac{20.00}{5.123} = b, \text{ 2d } \text{"} = 3.903$$

$$A = (\text{1st mean } a)\ (\text{1st mean } b) = 5.123 \times 3.922 = 20.092 = A, \text{ 2d approx.}$$

(Check for consistency, $A = 5.099 \times 3.903 = 19.901$.)

	a	b	A
Last mean value	5.123	3.922	20.00
2d approx. "	5.099	3.903	20.092
2d mean "	5.111	3.908	20.046

$$\text{Mean value} = \frac{\text{Last mean + last approx.}}{2}$$

$$a = \frac{\text{2d mean } A}{\text{2d mean } b} = \frac{20.046}{3.908} = 5.129 = a, \text{ 3d approx.}$$

$$b = \frac{\text{2d mean } A}{\text{2d mean } a} = \frac{20.046}{5.111} = 3.922 = b, \text{ 3d } \text{"}$$

$$A = (\text{2d mean } a)\ (\text{2d mean } b) = 5.111 \times 3.908 = 19.9737 = A, \text{ 3d approx.}$$

	a	b	A
Last mean value	5.111	3.908	20.046
3d approx. "	5.129	3.922	19.9737
3d mean "	5.120	3.915	20.0098

$$a = \frac{\text{3d mean A}}{\text{3d mean b}} = \frac{20.0098}{3.915} = 5.111 = a, \text{ 4th approx.}$$

$$b = \frac{\text{3d mean A}}{\text{3d mean a}} = \frac{20.0098}{5.120} = 3.908 = b, \text{ 4th } "$$

$$A = (\text{3d mean a})\ (\text{3d mean b}) = 5.120 \times 3.915 = 20.0448 = A, \text{ 4th approx.}$$

(Check for consistency, $5.111 \times 3.908 = 19.9738.$)

	a	b	A
Last mean value	5.120	3.915	20.0098
4th approx. "	5.111	3.908	20.0448
4th mean "	5.115	3.912	20.0273

$$a = \frac{\text{4th mean A}}{\text{4th mean b}} = \frac{20.0273}{3.912} = 5.119 = a, \text{ 5th approx.}$$

$$b = \frac{\text{4th mean A}}{\text{4th mean a}} = \frac{20.0273}{5.115} = 3.915 = a, \text{ 5th } "$$

$$A = (\text{4th mean a})\ (\text{4th mean b}) = 5.115 \times 3.913 = 20.0098 = A, \text{ 5th approx.}$$

(Check for consistency, $5.119 \times 3.915 = 20.0409.$)

	a	b	A
Last mean value	5.115	3.912	20.0273
5th approx. "	5.119	3.915	20.0098
5th mean "	5.117	3.914	20.0185

$$a = \frac{\text{5th mean A}}{\text{5th mean b}} = \frac{20.0185}{3.914} = 5.114 = \text{6th approx., } a$$

$$b = \frac{\text{5th mean A}}{\text{5th mean a}} = \frac{20.0185}{5.117} = 3.912 = \text{6th approx., } b$$

$$A = (\text{5th mean a})\ (\text{5th mean b}) = 5.117 \times 3.914 = 20.0279 = \text{6th approx., } A$$

(Check for consistency, $5.114 \times 3.912 = 20.0059.$)

	a	b	A
Last mean value	5.117	3.914	20.0185
6th approx. "	5.114	3.912	20.0279
6th mean "	5.1155	3.913	20.0237

$$a = \frac{\text{6th mean A}}{\text{6th mean b}} = \frac{20.0237}{3.913} = 5.1170 = a, \quad \text{7th approx.}$$

$$b = \frac{\text{6th mean A}}{\text{6th mean b}} = \frac{20.0237}{5.1155} = 3.9143 = b, \quad \text{7th} \quad "$$

A = (6th mean a) (6th mean b) = 5.1155 × 3.913 = 20.0169 = A, 7th approx.

(Check for consistency, 5.117 × 3.9143 = 20.0294.)

	a	b	A
Last mean value	5.1162	3.9136	20.0203
8th approx. "	5.1155	3.9131	20.02276
8th mean "	5.1158	3.9134	20.02153

$$a = \frac{\text{8th mean A}}{\text{8th mean b}} = \frac{20.02153}{3.9134} = 5.1161 = a, \quad \text{9th approx.}$$

$$b = \frac{\text{8th mean A}}{\text{8th mean a}} = \frac{20.03152}{5.1158} = 3.9136 = b, \quad \text{9th} \quad "$$

A = (8th mean a) (8th mean b) = 5.1158 × 3.9134 = 20.02017 = A, 9th approx.

(Check for consistency, 5.1161 × 3.9136 = 20.02236.)

Consistency exists to four (4) significant figures.

The desired values are then taken from the 9th approximation as follows: a = 5.116; b = 3.914; A = 20.02;

as check, ab = A = 5.116 × 3.914 = 20.0340.

Case 3.

Now let us consider as example two rectangles which actually exist, as follows:

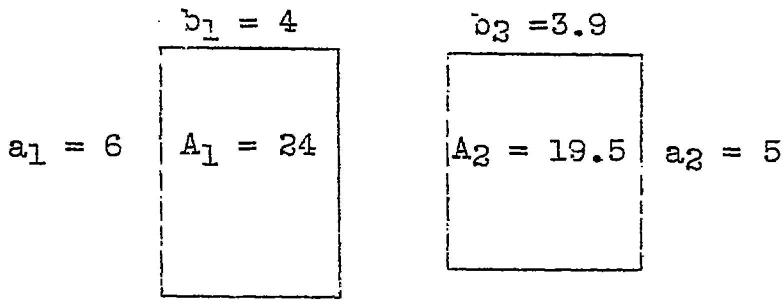

Fig.2

It is known (let us say) that human endeavor tried to make side b_1 = side b_2. This is analogous to two types of ships built say in the same year, with no apparent advancement in the art of propeller design compassed to the ships just before and just after the building of these two ships. It then is safe to say that these two ships would have as far as is known the same propeller efficiencies. On this relation that side b_1 = side b_2 the following will be worked out:

The reported values are

1st rectangle	2d rectangle	Mathematical relations in this case
$b_1 = 3.95$	$b_2 = 3.99$	$a_1 b_1 = A_1$
$a_1 = 6.08$	$a_2 = 4.94$	$a_2 b_2 = A_2$
$A_1 = 24.05$	$A_2 = 19.80$	$b_1 = b_2$

Assuming consistency to three significant figures is considered sufficient. Proceed similarly to Case 1.

$$a_1 = \frac{A_1}{b_1} = \frac{24.05}{3.95} = 6.088 = a_1, \quad \text{1st approx.}$$

$$b_1 = \frac{A_1}{a_1} = \frac{24.05}{6.08} = 3.955 = b_1, \quad \text{1st} \quad ''$$

$$a_2 = \frac{A_2}{b_2} = \frac{19.80}{3.99} = 4.962 = a_2, \quad \text{1st} \quad ''$$

$$b_2 = \frac{A_2}{a_2} = \frac{19.80}{4.94} = 4.008 = b_2, \quad \text{1st} \quad ''$$

$$A_1 = a_1\, b_1 = 6.08 \times 3.95 = 24.016 = A_1, \quad \text{1st approx.}$$

$$A_2 = a_2\, b_2 = 4.94 \times 3.99 = 19.710 = A_2, \quad \text{1st} \quad ''$$

Now consider the relation $b_1 = b_2$:

b_1, 1st approx. = 3.955

b_2, " " = 4.008

(mean value) cal. = 3.982 to be averaged into the mean values.

Last mean (in this case reported data):

	a_1	b_1	A_1	a_2	b_2	A_2
Last mean	6.08	3.95	24.05	4.94	3.99	19.80
1st approx.	6.088	3.955	24.016	4.962	4.008	19.710
(mean value) cal.		3.982			3.982	
1st mean value	6.084	3.962	24.033	4.951	3.993	19.755

It is to be noted that the assumption that $b_1 = b_2$ based on human endeavor is given equal weight with reported data and hence enters the mean value only once, having thus one-third effect on the mean values of b_1 and b_2. However, if (in the case

of ships) a certain data, say as obtained from deceleration tests is assumed to be highly correct, this can be given greater weight by averaging it on a weighted mean principle. On ships where the deceleration data looked reasonable it was given three times the weight of other reported values and was averaged in on each approximation, thereby forcing the dependent variables to closely conform to the actual deceleration test. To continue the case at hand -

Check for consistency:

$(a_1$, 1st approx.$)(b_1$, 1st approx.$) = 6.038 \times 3.955 = 24.078$

$(a_2$, " " $)(b_2$, " " $) = 4.962 \times 4.008 = 19.887$

Compared against the mean values of

$A_1 = 24.033$

$A_2 = 19.755$

$$a_1 = \frac{\text{1st mean } A_1}{\text{1st mean } b_1} = \frac{24.033}{3.962} = 6.065 = a_1, \quad \text{2d approx.}$$

$$b_1 = \frac{\text{1st mean } A_1}{\text{1st mean } a_1} = \frac{24.033}{6.084} = 3.950 = b_1, \quad \text{2d} \quad \text{"}$$

$$A_1 = (\text{1st mean } a_1)(\text{1st mean } b_1) = 6.084 \times 3.962 = 24.1048 = A_1, \text{ 2d approx.}$$

$$a_2 = \frac{\text{1st mean } A_2}{\text{1st mean } b_2} = \frac{19.755}{3.993} = 4.947 = a_2, \quad \text{2d approx.}$$

$$b_2 = \frac{\text{1st mean } A_2}{\text{1st mean } a_2} = \frac{19.755}{4.951} = 3.990 = b_2, \quad \text{2d} \quad \text{"}$$

$$A_2 = (\text{1st mean } a_2)(\text{1st mean } b_2) = 4.951 \times 3.993 = 19.7693 = A_2, \text{ 2d approx.}$$

Check for consistency:

(a$_1$, 2d approx.)(b$_1$, 2d approx.) = $A_1 = 6.065 \times 3.950 = 23.9567$

(a$_2$, 2d ")(b$_2$, 2d ") = $A_2 = 4.947 \times 3.990 = 19.738$ =

as compared against $A_1 = 24.1048$ b$_1$, 2d approx. = 3.950

$A_2 = 19.7693$ b$_2$, 2d " = 3.990

mean = 3.970

	a_1	b_1	A_1	a_2	b_2	A_2
Last mean	6.084	3.962	24.033	4.951	3.993	19.755
2d approx.	6.065	3.950	24.1048	4.947	3.990	19.7693
Mean value of b_1 & b_2		3.970			3.970	
2d mean	6.074	3.961	24.0689	4.949	3.984	19.7622

$$a_1 = \frac{\text{2d mean } A_1}{\text{2d mean } a_1} = \frac{24.0689}{3.961} = 6.0764 = a_1, \quad \text{3d approx.}$$

$$b_1 = \frac{\text{2d mean } A_1}{\text{3d mean } a_1} = \frac{24.0689}{6.074} = 3.9626 = b_1, \quad \text{3d} \quad "$$

$$A_1 = (\text{2d mean } a_1)(\text{2d mean } b_1) = 6.074 \times 3.961 = 24.0591 = A_1, \quad \text{3d approx.}$$

$$a_2 = \frac{\text{3d mean } A_2}{\text{2d mean } b_2} = \frac{19.7622}{3.984} = 4.9603 = a_2, \quad \text{3d approx.}$$

$$b_2 = \frac{\text{2d mean } A_2}{\text{2d mean } a_2} = \frac{19.7622}{4.949} = 3.9931 = b_2, \quad \text{3d} \quad "$$

$$A = (\text{2d mean } a_2)(\text{2d mean } b_2) = 4.949 \times 3.984 = 19.7168 = A_2, \quad \text{3d approx.}$$

Check for consistency:

(a$_1$, 3d approx.)(b$_1$, 3d approx.)= $A_1 = 6.0764 \times 3.9626 = 24.0783$

(a$_2$, " ")(b$_2$, " ")= $A_2 = 4.9603 \times 3.9931 = 19.8069$

as compared against

$A_1 = 24.0591$

$A_2 = 19.7168$

b_1, 2d approx. = 3.9626

b_2, " " = 3.9931

mean = 3.9778

	a_1	b_1	A_1	a_2	b_2	A_2
Last mean	6.074	3.961	24.0689	4.949	3.984	19.7622
3d approx.	6.0764	3.9626	24.0591	4.9603	3.993	19.7168
mean value b_1 & b_2		3.9778			3.9778	
3d mean	6.0752	3.9671	24.0640	4.9546	3.9849	19.7395

$$a_1 = \frac{\text{3d mean } A_1}{\text{3d mean } b_1} = \frac{24.0640}{3.9671} = 6.0658 = a_1, \quad \text{4th approx.}$$

$$b_1 = \frac{\text{3d mean } A_1}{\text{3d mean } a_1} = \frac{24.0640}{6.0752} = 3.9610 = b_1, \quad \text{4th} \quad "$$

$$A_1 = (\text{3d mean } a_1)(\text{3d mean } b_1) = 6.0752 \times 3.9671 = 24.1009 = A_1, \text{ 4th approx.}$$

$$a_2 = \frac{\text{3d mean } A_2}{\text{3d mean } b_2} = \frac{19.7395}{3.9849} = 4.9535 = a_2, \quad \text{4th approx.}$$

$$b_2 = \frac{\text{3d mean } A_2}{\text{3d mean } a_2} = \frac{19.7395}{4.9546} = 3.9840 = b_2, \quad \text{4th} \quad "$$

$$A_2 = (\text{3d mean } a_2)(\text{3d mean } b_2) = 4.9546 \times 3.9849 = 19.7436 = A_2, \text{ 4th approx.}$$

Check for consistency:

$(a_1$, 4th approx.$)(b_1$, 4th approx.$) = A_1 = 6.0658 \times 3.9610 = 24.0266$

$(a_2$, " " $)(b_2$, " " $) = A_2 = 4.9535 \times 3.9840 = 19.7347$

as against

$A_1 = 24.1009$

$A_2 = 19.7436$

It is seen that rectangle No. 2 has reached consistency to three significant figures as specified, which are for engineering purposes.

$$a_2 = 4.95 \quad b\ 3.98 \quad A_2\ 19.7$$

For check $4.95 \times 3.98 = 19.7010$

Thus the value of $b_2 = 3.98$ can be averaged into the next approximation, the same as the mean of b_1 and b_2 was formerly. The next approximation need only be carried out on rectangle No. 1 -

Thus:

Last mean	=	6.0752	3.9671	24.0640
4th approx.	=	6.0658	3.9610	24.1009
b_2	=		3.98	
4th mean	=	6.0705	3.9649	24.0825

$$a_1 = \frac{A\ \text{4th mean}}{b\ \text{4th mean}} = \frac{24.0825}{3.9694} = 6.0670 = a_1, \quad \text{5th approx.}$$

$$b_1 = \frac{A\ \text{4th mean}}{a\ \text{4th mean}} = \frac{24.0825}{6.0705} = 3.9671 = b_1, \quad \text{5th} \quad ''$$

$A_1 = (\text{4th mean } a_1)(\text{4th mean } b_1) = 6.0705 \times 3.9694 = 24.0962 = A_1$, 5th approx.

Check for consistency (a_1, 5th approx.)(b_1, 5th approx.) = $6.067 \times 3.9671 = 24.068$.

It is seen that rectangle No. 1 has reached consistency to three significant figures as specified which are for engineering purposes.

$a_1 = 6.07 \quad b_1 = 3.97 \quad A_1 = 24.09$ or 24.1 for 3 figures

Check $6.07 \times 3.97 = 24.0979$.

It is here well to note that although human endeavor tried to make $b_1 = b_2$ it was so tempered by the reported values of b_1 and b_2 that they never did quite equal each other. Thus final values $b_1 = 3.97$ and $b_2 = 3.98$.

So it can be seen that even though an assumption was made that the propeller efficiency of one ship is equal to that of another, they do not necessarily in the final values equal each other unless the reported data agrees close enough to make it so.

The interconnecting quantities between ships where no data were available were propeller efficiencies and drag coefficients.

The data obtained by direct observation are maximum speed and horsepower; drag coefficient (with dead or idling propellers as was the case at the given deceleration test).

The data calculated from observed data are drag coefficient with engines having no propeller drag, propeller efficiency, maximum speed and propulsive coefficient.

The data obtained where no deceleration test had been run were to consider as reported data a drag coefficient that lay between the ships built just before and after with due regard to fineness ratio, type of cars and surfaces, contours of hull, etc. This assumed drag coefficient was forced by Lipka's method to vary if necessary to accommodate the drag coefficient as calculated from maximum speed, horsepower and propeller efficiency or from area of drag. Likewise, in ships where propeller effici-

ency was not known by any data, it was assumed as between the ships on either side of it. This could not be much in error as propeller efficiency at maximum speed was almost a continuous function. Then again the area of drag as found for ships on which deceleration test had been run, was seen to be nearly a continuous function from one design to another. So where reported data were missing (two cases only) these assumptions were made.

Great weight was given to the drag coefficients and propeller efficiencies as obtained from an actual known deceleration test. This was done by averaging this observed data in on each successive mean value; thereby forcing the conflicting reported data to conform to the deceleration test data. In some cases two deceleration tests of the same ship were found and they differed in drag coefficient and propeller efficiencies. In such cases an average value was used for the initial reported data. After the fifth approximation the relative value of each quantity compared to the same value of ships on each side of it was maintained by averaging in this interpolated value of drag coefficient and propeller efficiency. These two quantities determined all the rest for each individual ship so gave twice the number of calculated values for quantities. Thus, on a particular ship a value of drag coefficient would be arrived at from the data pertaining to that particular ship and another value of its drag coefficient would be arrived at by its relation to the ship's

"items" on each side of it, which amounts to this: digest all reported observed data (giving great weight to deceleration tests) for five approximations, then calculate the relative values of similar quantities between each item in succession. Then on each successive approximation, average in to its mean the interpolated values of drag coefficients and propeller efficiencies. Thus the relative values of quantities would have nearly the same relation between ships as found to exist on the fifth approximation and would be found to exist in the final analysis.

Body of Report

Preliminary calculations of data, and empirical digest of reported and deceleration test data to obtain consistent values of all necessary quantities.

Lipka's empirical method was used. This method, as explained in the introduction, gives consistent results by changing values that lie off the mean by arbitrarily moving (by averaging) them half way to that mean and then calculating the dependent variables. This was done for six dependent quantities: maximum air speed, horsepower at maximum speed, propulsive coefficient at maximum speed, propeller efficiency at maximum speed, area of drag, and whole ship's drag coefficient.

It was found that the data thought reliable often moved slightly as it was not always consistent.

Preliminary approximate calculations were made on the relative total drag of each ship, its approximate skin friction, resistance of the bare hull, etc. This was done purely to get a convenient arrangement of the ships, and not intended to be the basis for the subdivision of a ship's drag into its component parts, as bare hull resistance and skin friction are only very approximate. Part II (Technical Note No. 248) deals entirely with the subdivision of the drag of airships.

The quantity S = "characteristic length" with power on and power off, was carried along through three approximations primarily to give a more accurate start to the system of approximations.

Consistent results were obtained in eleven approximations when most quantities showed a rapidly converging series of their differences with the previous approximation, and the differences yet to be so small as to show such a small numerical change in the dependent quantities that the limits of these series were taken as the final consistent values. The final values were then checked against each other by the formulas of their relations (See Tables I to VIII given at the end of report).

Assumptions

The justification for the relations between ships is based on these assumptions. The art of propeller design for airships showed nearly a continuous function over the time. The propel-

ler efficiencies gave several points on this function. It then was safe to assume that the propeller efficiency of a ship on which no deceleration data could be found was between that obtained on the ships before and the ships after. This assumed propeller efficiency was given equal weight with reported (not deceleration test data) data on the first approximation. The same was done for whole ship's drag coefficient on the ships where no deceleration tests had been run, taking into account type of hull, volume, type of cars, surfaces, etc., and so, in fact, it became an interpolated value of the drag coefficient for use on the first approximation.

Each ship's data were then run independently of other ships for five approximations, giving greater weight to deceleration test data where available. At the end of the fifth approximation the values of C and E were compared to the items on each side of it and this relative position was kept by averaging in these new interpolated values on all the approximations that follow.

Symbols and Definitions Used in Part I

L = Length of ship in feet.

D = Maximum diameter of hull in feet.

υ = Air speed in ft./sec.

$\upsilon_{max.}$ = Air speed at full throttle all engines.

$\frac{L}{D}$ = Fineness ratio.

A = Maximum cross sectional area in sq.ft.

V or Vol. = Air volume of hull in cu.ft.

$\frac{V}{AL}$ = Cylindrical coefficient.

X = Distance from nose to maximum diameter in feet.

X Also used to indicate type of series as in $X, \frac{X}{2}, \frac{X}{4} \ldots\ldots 0$.

r = Maximum radius of hull in feet.

e = Eccentricity of nose ellipse.

A_s = Total surface area of hull in sq.ft.

S.F. = Skin friction.

K_p = Approx. drag coef. due to pressure difference.
K_s = " " " " " skin friction.
K = " " " " " hull.
Used only in first approximations.

K = Propulsive coefficient in last approximations and final summaries.

P_o = Full rated horsepower.

$HP_{max.}$ = Full developed horsepower at full throttle all engines.

η = A term that approaches propeller efficiency E.

E = Propeller efficiency for whole ship.

$E_{max.}$ = Propeller efficiency with $v_{max.}$ and HP_{max}.

ρ = Density of the air; consistently used as a constant of .00237 slugs/cu.ft.

V_M = Virtual volume in cu.ft.

S = Characteristic length in feet.

S_P = " " with power on in feet.

A = Area of drag in sq.ft.

A_P = " " " with power on in feet.

C = Drag, coefficient of whole ship in absolute units.

Note.- Subscript numerals denote the number of the approximation.
Primes (as K', K", K''')" " " " " "
in the first few approximations.
Where there are any approximations on a sheet, the whole sheet is labeled "Preliminary Calculations." This is to prevent misuse of this article.
Final results of Part I are summarized on Page 3.

Formulas

$$HP._{available} = C \times \frac{\rho}{2} \times \frac{Vol.^{2/3}\ \upsilon^3}{550\ E}$$

$HP._r$ = Horsepower useful in line of flight.

$$E = \frac{HP._r}{HP._{available}} = \frac{D\ \upsilon}{550\ HP._{available}}$$

$$K = \text{Propulsive coeff.} = \frac{2E}{C} = \frac{2E(Vol.)^{2/3}}{A_P} = \frac{\rho\ \upsilon^3 (Vol.)^{2/3}}{550\ HP._r}$$

A_ρ = Area of drag with power on (sq.ft.).

$$A_P = \frac{\text{Drag in pounds}}{\frac{\rho\ \upsilon^2}{2}}$$

ρ = slugs/cu.ft.
υ = ft./sec.
A_P = sq.ft.

C = Drag coefficient (absolute units).

$$C = \frac{\text{Drag in pounds}}{\frac{\rho}{2}\ \upsilon^2 (Vol.)^{2/3}} = \frac{2E}{K}$$

$$C = \frac{A_P}{(Vol.)^{2/3}} \quad \text{(absolute units).}$$

$$K = \frac{2E(Vol.)^{2/3}}{A_P} = \frac{2E}{C} = \frac{\rho\ \upsilon^3 (Vol.)^{2/3}}{550\ HP.}$$

$$A_P = \frac{2V_M}{S_P}$$

V_M = virtual volume in cu.ft. = Vol. + $\frac{\pi r^3}{3}$
(r = max. radius of cross section).
S_P = characteristic length, power on (ft.).

$$A_{power\ off} = \frac{2V_M}{S_{power\ off}}$$

$S_{power\ off}$ found from deceleration curve.

$A_P - A_{power\ off}$ = Area of drag, due to idle propellers.

ρ = .00237 slugs/cu.ft. (All foregoing data based on the standard density of air.)

Formulas (Cont.)

$\upsilon_{max.}$ = Velocity; air speed in ft./sec.

$$\upsilon_{max.} = \sqrt[3]{\frac{HP. \times 2 \times 550 \times E}{C \frac{\rho}{2} (Vol.)^{2/3}}}$$

(HP. = Max. HP. available.)
(E = Prop. Eff. at $\upsilon_{max.}$ and $HP._{max.}$)

$$\upsilon = \sqrt[3]{\frac{HP. \times 2 \times 550 \times E}{C \frac{\rho}{2} (Vol.)^{2/3}}}$$

(HP. = any available HP.)
(E = Prop. Eff. at υ and HP.)

$$D = C \frac{\rho}{2} \upsilon^2 (Vol.)^{2/3} = \text{Drag in pounds.}$$

$$= \rho\, V_M \frac{d\upsilon}{dt} = A_P \frac{\rho \upsilon^2}{2}$$

$$HP._r = \frac{D\,\upsilon}{550}$$

υ = ft./sec.
D = pounds

$$\frac{dt}{d\upsilon} = \frac{S}{\upsilon^2}$$ (S = characteristic length);

$$S_{power\ off} = \frac{t}{\frac{1}{\upsilon_0} - \frac{1}{\upsilon}}$$

(From slope of $\frac{1}{\upsilon}$ plotted against t during deceleration test.)

Conclusion

1. The consistent values obtained in the body of this report and given again in the Summary must be used in the light of the method by which they were obtained. Thus, it must be realized that the net errors on reported data compared to what actually exists, are pro-rated around and that errors in deceleration test data are likewise pro-rated around until consistency is obtained. It can then be said that the values herein obtained are the probable relative values and thus for design and research purposes can be considered as a digest of past performance and deceleration data.

2. Part II (T.N. No. 248) deals with the subdivision of the Drag of Airships and this work presents (by the author) the point of preliminary calculations and a first VL curve for full size bare airship hulls.

3. The range of application of the data obtained in Part I can not logically be applied to new designs that are not nearly similar to airships from which those data were obtained. However, on the judgment of the designer, certain quantities such as drag coefficient and propeller efficiency may be used for ships of larger volumes, the accuracy of the results will largely depend on the assumptions made. Part II (T.N. No. 248) endeavors to devise a method of calculating quantities concerning a new design.

References

N.A.C.A. Technical Memorandum No. 237* - "Rigid Airships" by Friedrich Stahl, November, 1923.

N.A.C.A. Technical Report No. 117 - "The Drag of Zeppelin Airships" by Max M. Munk, 1921.

N.A.C.A. Technical Report No. 184 - "The Aerodynamic Forces in Airship Hulls" by Max M. Munk, 1924.

N.A.C.A. Technical Note No. 194 - "A Method of Determining the Dimensions and Horsepower of an Airship for any Given Performance" by C. P. Burgess, 1924.

Bureau of Aeronautics (U.S. Navy) Design Memos Nos. 30, 41, 43, 44 and 47, by C. P. Burgess.

Various Papers by Prandtl, Furman, Blasius and Stanton.

U.S. Navy Bu. C. & R. Bulletin No. 101, Dec. 1919.

"The Rigid Airship, ZR-3" by C. P. Burgess, published in Journal A.S.N.E., November, 1924.

Reports on Airship Models, by Eiffel, 1918.

Classroom Notes from Professors E. P. Warner and Lipka, Mass. Institute of Technology.

In addition to data and formulas taken from the above, the following data obtained from German sources are considered. (Where data for more than one ship in an item was given, the average is tabulated here.)

Additional Reported Data

Item	Air Volume cu.ft.	Dist.max. Ord.from Nose % length	Prop. Coef. K	Prop. Eff. at $v_{max.}$ E	Drag Coef. C*	Remarks
8		17.50	16	36		
9	573000	25.80	10	28	.056	Formula $C = \frac{2E}{K}$ does not always hold true with this data.
10		23.63	16	33	.044	
11		25.00	19	66	.071	
12		24.61	26	59	.052	
13		22.40	19	57	.048	
14	858000	22.19	24	55	.055	
15		21.62	32	56	.035	
16		21.40	32	58	.032	
17		19.62	36	54	.030	
18	2149000	30.80	39	56	.029	
19		30.80	47	61	.021	
20		30.80	56	61	.020	
21		30.80	57	32	.020	On this item, data states skin friction = 82% hull drag.
22	2640000	24.40	58	64	.020	
23		24.40	59	65	.019	
24		30.80	59	65	.020	
25	2400000	24.40	56	65	.020	

In general this data conflicts with that given in the references. It is thus considered as reported data.

A statement in the above reported data, that skin friction = constant × $V^{-.047}$ = % of hull drag (where V = volume of hull) is not consistent with data reported for item 22.

*For whole ship.

[illegible] RESULTS

[illegible] PURPOSE[illegible]

A_P Drag Area (Power On)	C Drag Coeff. (Whole Ship)
87.40	.047582
127.40	.039962
131.49	.039807
78.00	.037[illegible]61
77.01	.037945
170.01	.019[illegible]6
3[illegible].99	.018[illegible]
251.00	.046234
383.01	.055518
374.00	.045973
563.00	.071371
412.00	.050191
482.00	.056547
409.00	.054298
333.98	.036262
393.00	.034422
369.47	.030068
474.00	.028540
423.00	.025505
372.00	.022402
371.00	.022340
419.00	.021935
424.[illegible]	.022198
[illegible]	.022400
[illegible]	.02[illegible]538
[illegible]	.0[illegible]31[illegible]

— FORMULAE —

$HP_{AVAILABLE} = C \times \frac{S}{?} = \frac{Vol^{\frac{2}{3}} U^3}{550\,E}$ [illegible]

HP_T = Horse Power Useful In Line Of Flight

$E = \frac{HP_T}{HP_{AVAILABLE}} = \frac{DU}{550\,HP_{AVAILABLE}}$

K = Propulsive Coeff. $= \frac{2E}{C} = \frac{2E(Vol)^{\frac{2}{3}}}{A_P} = \frac{\rho U^3 (Vol)^{\frac{2}{3}}}{550\,HP}$ [illegible]

A_P = Area Of Drag With Power On [illegible]

$A_P = \frac{\text{Drag In Pounds}}{\frac{\rho}{2}U^2}$ [illegible]

C = Drag Coeff. (Absolute Units)

$C = \frac{\text{Drag In Pounds}}{\frac{\rho}{2} U^2 (Vol)^{\frac{2}{3}}} = \frac{2E}{K}$

$C = \frac{A_P}{(Vol)^{\frac{2}{3}}}$ (Abs Units)

$K = \frac{2E(Vol)^{\frac{2}{3}}}{A_P} = \frac{2E}{C} = \frac{\rho U^3 (Vol)^{\frac{2}{3}}}{550\,HP}$

$A_P = \frac{2\,V_M}{S_P}$ — V_M = Virtual Volume In Cu. Ft. = $Vol + \frac{\pi r^3}{3}$ (r = [illegible] Radius Of Cross Section); S_P = Characteristic Length, Power On, [illegible]

$A_{POWER\ OFF} = \frac{2\,V_M}{S_{POWER\ OFF}}$ — $S_{POWER\ OFF}$ Found From Deceleration [illegible]

$A_P - A_{POWER\ OFF}$ = Area Of Drag Due To Idle Propellers

ρ = .00237 Slugs/[illegible] ([illegible] Foregoing Data Based On The Standard [illegible] Of Air)

U_{MAX} = Velocity, Air Speed [illegible] Ft. Sec.

$U_{MAX} = \sqrt[3]{\frac{HP \times 2 \times 550 \times E}{C\,\rho\,(Vol)^{\frac{2}{3}}}}$ [illegible]

$U = \sqrt[3]{\frac{HP \times 2 \times 550 \times E}{C\,\rho\,(Vol)^{\frac{2}{3}}}}$ [illegible]

$D = C \frac{\rho}{2} U^2 (Vol)^{\frac{2}{3}}$ = Drag In Pounds [illegible]

$HP_T = \frac{DU}{550}$ [illegible]

[illegible]

[illegible]

TABLE VII

P[illegible] [illegible]INARY CALCULATIONS
FIGURES ON THIS SHEET ARE ONLY APPROXIMATE

ITEM	Converging Series of ΔA_P: 1st Term $A_{P1}-A_{P0}$	2nd Term	3rd Term	ΔA_P Limit 0.00	A_P Limit Drag Area Power Off Sq. Ft.	[illegible] $A_P = (Vol)^{2/3} 2E_{lim} / K_{lim}$ Check for A_P Limit	Check or Error	C calc'd $\left(\frac{A_P \text{ Limit}}{Vol^{2/3}}\right)$ Used Five Place Logs	HP calc'd Check for HP Limit	Check or Error	Summary Relative Values of: U_{max} Ft/Sec	HP max	K (Prop Coeff)	E Prop. Eff. **
1					87.40	87.40	Check	.045582	99.46	Check	69.00	99.46	27.63	.622
2					127.40	127.40	″	.039962	29[illegible].4[illegible]	″	88.00	296.42	31.59	.631
3	- .63	- .31	- .16	0.00	131.49	149.50	″	.039789	250.00	″	85.11	250.00	32.78	.650
4					78.00	78.00	″	.037464	153.10	″	82.20	153.10	32.35	.610
5	+ .3	+ .07	+ .03	0.00	79.01	79.00	″	.037946	126.80	″	77.30	126.80	32.68	.620
6	+ .83	- .44	+ .22	0.00	170.01	170.00	″	.019774	958.90	″	119.99	958.89	66.76	.660
7	- .5	.38	- .19	0.00	356.99	357.00	″	.018125	2017.00	″	115.00	2017.00	64.[illegible]	.580
8	- .50	- .25	- .13	0.00	251.00	251.02	Check	.046233	27.64	Check	26.40	27.63	15.98	.360
9	- 3.50	- 1.75	- .87	0.00	383.01	383.00	″	.055580	207.90	″	41.00	202.93	10.08	.280
10					374.00	374.00	″	.045963	343.34	″	51.98	343.34	14.36	.330
11					563.00	563.00	″	.071371	447.91	″	62.40	347.88	18.44	.658
12					412.00	412.00	″	.050189	478.90	″	67.50	479.89	24.45	.570
13					487.00	482.00	″	.056547	592.70	″	66.69	592.71	18.47	.520
14					409.00	409.00	″	.045298	592.71	″	70.89	592.68	23.40	.530
15					333.98	333.98	″	.036261	592.37	″	77.09	591.40	30.51	.540
16					393.00	393.00	″	.034423	836.49	″	81.61	836.58	31.96	.550
17	- .13	.01	- .03	0.00	369.49	369.50	″	.030079	955.40	″	86.00	959.39	35.25	.530
18					474.00	474.00	″	.028544	1465.80	″	97.40	1465.80	38.52	.550
19					423.00	423.00	″	.025475	1215.80	″	92.41	1215.81	46.65	.594
20					372.00	372.00	″	.022401	1189.30	″	96.19	1189.30	53.57	.600
21					371.00	371.00	″	.022340	1191.30	″	97.40	1191.80	55.51	.620
22					419.00	419.00	″	.0219[illegible]	[illegible]	″	74.29	1201.60	5[illegible].44	.6[illegible]
23					426.00	42[illegible]	″	.022[illegible]	1193.7[illegible]	″	74.19	1193.71	51.66	.640
24					372.00	372.00	″	.0224[illegible]	14[illegible]	″	104.81	1441.39	57.[illegible]	.640
25					404.00	404.00	″	.022539	1998.[illegible]	″	113.12	1998.81	55.91	.630
26	+ .38	+ .19	+ .09	0.00	407.51	407.51	″	.023[illegible]	1959.50	″	91.00	1959.11	36.34	.475
	x	1/2	1/4	[illegible]				*						

[illegible] * — This column checks with $2E_{lim}$ / [illegible] [illegible] to the exception of 5 items with [illegible] [illegible] column is considered [illegible].

† x, $\frac{1}{2}$ & $\frac{1}{4}$ show type of series.

** This column gives [illegible] [illegible]

...erging Series of ΔK: 2nd Term $K_{10}-K_9$	3rd Term $K_{11}-K_{10}$	ΔK Limit ... 0	K Limit (Prop. Comp.) $K_{11}+(K_{11}-K_{10})$	E_9 Limit Except ZR-1 Where C_{11} is Limiting	C (Drag Coeff.) 11th App.	ΔC $(C_{11}-C_{10})10^4$	Converging Series on ΔC: 1st T. $(C_9-C_8)10^4$	2nd T. $(C_{10}-C_9)10^4$	3rd T. $(C_{11}-C_{10})10^4$	ΔC Lim. ... 0.00	Drag Coefficient: C Limit $C_{11}+(C_{11}-C_{10})$	C Calculated $\frac{2E_{LIMIT}}{K_{LIMIT}}$ Check Against C Limit (5 Place Logs)	$C_{LIM}-C_{CALC.}$ Check or Error.	A_P Drag Area Power On Sq. Ft. 11th App. Except Where $A_{10}-A_9=0$	ΔA_P $A_{P11}-A_{P10}$
+.06	+.03	0.00	27.63	.622	.045583	−.01	−.05	−.02	−.01	0.00	.045582	.045582	Check		
+.01	+.01	0.00	31.59	.631	.039762	0.00					.039962	.039962	"		
−.04	−.02	0.00	32.78	.650	.039780	+.27	+1.04	+.54	+.27	0.00	.039807	.039789	+.000018	131.65	−.16
−.10	−.05	0.00	32.55	.610	.037564	−.03	−.10	−.05	−.03	0.00	.037561	.037464	+.000097		
−.07	−.03	0.00	32.68	.620	.037911	+.34	+1.36	+.68	+.34	0.00	.037945	.037946	Check.	78.98	+.03
−.33	−.16	0.00	66.76	.660	.019752	+.24	+.97	+.48	+.24	0.00	.019776	.019776	"	169.79	+.22
+.07	+.04	0.00	64.03	.580	.018736	−.11	−.44	−.22	−.11	0.00	.018125	.018125	"	357.18	−.19
+.03	+.01	0.00	15.58	.360	.046263	−.29	−1.16	−.58	−.29	0.00	.046234	.046233	Check.	251.13	−.13
−.03	−.01	0.00	10.08	.280	.055505	+.73	+2.95	+1.47	+.73	0.00	.055578	.055580	"	383.88	−.87
+.02	+.01	0.00	14.36	.330	.046004	−.31	−1.36	−.62	−.31	0.00	.045973	.045963	+.000010		
			18.44	.658	.071379	−.08	−.32	−.16	−.08	0.00	.071371	.071371	Check		
+.32	+.16	0.00	24.45	.570	.050291	−1.00	−4.03	−2.01	−1.00	0.00	.050191	.050189	"		
+.07	+.04	0.00	18.42	.520	.056644	−.97	−3.89	−1.94	−.97	0.00	.056547	.056547	"		
+.10	+.05	0.00	23.40	.530	.054329	−.31	−1.26	−.63	−.31	0.00	.054298	.054298	"		
+.10	+.06	0.00	30.51	.540	.036270	−.08	−.35	−.17	−.08	0.00	.036262	.036261	"		
			31.96	.550	.034427	−.05	−.20	−.10	−.05	0.00	.034422	.034423	"		
−1.07	−.53	0.00	35.25	.530	.029706	+3.62	+14.70	+7.35	+3.62	0.00	.030068	.030079	−.000011	369.52	−.03
−.11	.06	0.00	38.52	.550	.028532	+.08	+.36	+.16	+.08	0.00	.028540	.028544	Check.		
−.04	−.02	0.00	46.65	.594	.025489	+.16	+.66	+.33	+.16	0.00	.025505	.025473	+.000032		
−.03	−.01	0.00	53.57	.600	.022395	+.07	+.29	+.13	+.07	0.00	.022402	.022401	Check.		
−.15	−.07	0.00	55.51	.620	.022306	+.34	+1.35	+.67	+.34	0.00	.022340	.022340	"		
−.02	−.01	0.00	57.44	.630	.021933	+.02	+.09	+.04	+.02	0.00	.021935	.021936	"		
			57.66	.640	.022198	0.00					.022198	.022198	"		
			57.14	.640	.022400	0.00					.022400	.022400	"		
+.01	+.01	0.00	55.91	.630	.022542	−.04	−.15	−.08	−.04	0.00	.022538	.022539	"		
			36.34	.425	.023161	+.11	+.43	+.22	+.11	0.00	.023172	.023170	"	402.42	+.09
Of Accuracy ±.01 $\frac{X}{2}$ 1 $\frac{X}{4}$ ... 0															

Calculations by Clinton H. Havill
Lieut., U.S. Navy.

TABLE VII

PRELIMINARY CALCULATIONS

FIGURES ON THIS SHEET ARE ONLY APPROXIMATE

ITEM	Converging Series of ΔU: 1st Term $U_9 - U_8$	2nd Term $U_{10} - U_9$	3rd Term $U_{11} - U_{10}$	ΔU Limit ----0	U Limit. $U_{MAX} = U_{11} + (U_{11} - U_{10})$ Ft./Sec.	HP_{MAX} 11th Approx.	ΔHP. $HP_{11} - HP_{10}$	Converging Series of ΔHP: 1st Term $HP_9 - HP_8$	2nd Term $HP_{10} - HP_9$	3rd Term $HP_{11} - HP_{10}$	ΔHP Limit -- 0	HP Limit HP_{MAX} $HP_{11} + (HP_{11} - HP_{10})$	K (Prop. Coeff.) 11th App.	ΔK $K_{11} - K_{10}$	Conv… 1st Term $K_9 - K_8$
1					69.00	99.49	-0.03	- 0.14	- 0.07	-0.03	0.00	99.46	27.60	+ .03	+.11
2					88.00	296.65	-0.23	- 0.89	- 0.45	-0.23	0.00	296.42	31.58	+.01	+.02
3	-.57	-.29	-.14	0.00	83.11	250.00	0.00					250.00	32.80	- .02	-.08
4					82.20	152.91	+0.19	+ 0.78	+0.39	+0.19	0.00	153.10	32.60	- .05	-.19
5					77.30	126.69	+0.11	+ 0.45	+0.23	+0.11	0.00	126.80	32.71	- .03	-.14
6	-.03	-.01	-.01	0.00	119.99	958.96	-0.07	- 0.28	-0.14	-0.07	0.00	958.89	66.92	- .16	-.66
7					115.00	2017.81	-0.81	- 3.25	-1.63	-0.81	0.00	2017.00	63.99	+ .04	+.13
8					26.40	27.72	-0.09	- 0.34	-0.17	-0.09	0.00	27.63	15.57	+ .01	+.05
9					41.00	202.74	+0.19	+0.73	+0.37	+0.19	0.00	202.93	10.09	- .01	-.06
10	-.12	-.07	-.04	0.00	51.98	344.38	-1.04	-4.17	-2.08	-1.04	0.00	343.34	14.35	+ .01	+.04
11					67.40	448.02	-0.14	-0.53	-0.27	-0.14	0.00	347.88	18.44	.00	
12	-.13	-.06	-.03	0.00	67.50	481.21	-1.32	-5.28	-2.64	-1.32	0.00	479.89	24.29	+.16	+.64
13	-.09	-.04	-.02	0.00	66.69	588.79	+3.92	-15.68	-7.84	-3.92	0.00	592.71	18.38	+.04	+.13
14	-.15	-.08	-.04	0.00	70.89	595.02	-2.34	- 9.33	-4.67	-2.34	0.00	592.68	23.35	+.05	+.20
15	-.13	-.07	-.03	0.00	77.09	594.05	-2.15	- 8.61	-4.31	-2.15	0.00	591.40	30.45	+.06	+.20
16	-.10	-.05	-.02	0.00	81.61	837.40	-0.82	- 3.38	-1.64	-0.82	0.00	836.58	31.96	.00	
17	+1.00	+.50	+.25	0.00	86.00	955.68	-0.29	-1.15	-0.58	-0.29	0.00	959.39	35.78	-.53	-2.14
18	+ .93	+.46	+.23	0.00	92.40	1464.19	+1.61	+645	+3.23	+1.61	0.00	1465.80	38.58	-.06	-.22
19	+.95	+.98	+.19	0.00	92.41	1214.82	+0.99	+3.95	+1.98	+0.99	0.00	1215.81	46.67	-.02	-.09
20	-.15	-.08	-.04	0.00	96.19	1189.97	-0.67	-2.67	-1.34	-0.67	0.00	1189.30	53.58	-.01	-.06
21	-.25	-.13	-.06	0.00	97.40	1191.84	-0.54	-2.18	-1.09	-0.54	0.00	1191.30	55.58	-.07	-.30
22	-.03	-.01	-.01	0.00	94.29	1201.50	+0.10	+0.40	+0.20	+0.10	0.00	1201.60	57.45	-.01	-.04
23	-.03	-.02	-.01	0.00	94.19	1193.63	-0.42	-1.70	-0.85	-0.42	0.00	1193.21	57.66	.00	
24	-.05	-.02	-.01	0.00	104.81	1441.93	-0.54	-2.16	-1.08	-0.54	0.00	1441.39	57.14	.00	
25	+.03	-.02	-.01	0.00	113.12	1998.88	-0.07	-0.30	-0.15	-0.07	0.00	1998.81	55.90	+.01	+.03
26	-.25	-.13	-.06	0.00	91.00	1562.84	-3.13	-12.52	-6.26	-3.13	0.00	1559.71	36.34	.00	
	Limits of Accuracy - ±.01 x	x/2	x/4	→ 0				Limits of Accuracy - ±.01 x	x/2	x/4	→ 0				Limit x

NOTE: EXPRESSIONS x, x/2 & x/4 SHOW THE TYPE OF SERIES

App.	ΔE $E_9 - E_8$	A_P Power On 9th App.	ΔA_P $A_{P9} - A_{P8}$	v_{MAX} Ft./Sec. 10th App	Δv_{MAX} $v_{10} - v_9$	HP_{MAX} 10th App.	ΔHP $HP_{10} - HP_9$	K (Prop Coeff) 10th App.	ΔK $K_{10} - K_9$	C (Drag Coeff) 10th Approx.	ΔC $C_{10} - C_9$	A_P (Power On) 10th App.	ΔA $A_{10} - A_9$	v_{MAX} Ft./Sec. 11th App.	Δv_{MAX} $v_{11} - v_{10}$
22	.000	87.40	0.00	69.00	0.00	99.52	-0.07	27.57	+0.06	.045984	-.000002	87.40	0.00	69.00	0.00
31	"	127.40	0.00	88.00	0.00	296.88	-0.45	31.57	+0.01	.039962	.000000	127.40	0.00	88.00	0.00
50	"	132.12	-0.63	83.59	-0.29	250.00	0.00	32.82	-0.04	.039753	+.000054	131.81	-0.31	83.25	-0.14
10	"	78.00	0.00	82.20	0.00	152.72	+0.39	32.65	-0.10	.037567	-.000005	78.00	0.00	82.20	0.00
20	"	78.88	+0.13	77.30	0.00	126.58	+0.23	32.74	-0.07	.037877	+.000068	78.95	+0.07	77.30	0.00
0	"	169.13	+0.88	120.01	-0.01	959.03	-0.14	67.08	-0.33	.019728	+.000048	169.57	+0.44	120.00	-0.01
0	"	357.75	-0.75	115.00	0.00	2018.62	-1.63	63.95	+0.07	.018147	-.000022	357.37	-0.38	115.00	0.00
60	.000	251.51	-0.50	26.40	0.00	27.81	-0.17	15.56	+0.03	.046292	-.000058	251.26	-0.25	26.40	0.00
80	"	386.50	-3.50	41.00	0.00	202.59	+0.37	10.10	-0.03	.055432	+.000147	384.75	-1.75	41.00	0.00
30	"	374.00	0.00	52.06	-0.07	349.42	-2.08	14.34	+0.02	.046035	-.000062	374.00	0.00	52.02	-0.04
58	"	563.00	0.00	62.40	0.00	448.16	-0.27	18.44	+0.01	.071387	-.000016	563.00	0.00	62.40	0.00
70	"	412.00	0.00	67.56	-0.06	482.53	-2.64	24.13	+0.32	.050391	-.000201	412.00	0.00	67.53	-0.03
20	"	482.00	0.00	66.75	-0.04	584.87	+7.84	18.34	+0.07	.056741	-.000194	482.00	0.00	66.71	-0.02
30	"	409.00	0.00	70.97	-0.08	597.36	-4.67	23.30	+0.10	.054360	-.000063	409.00	0.00	70.93	-0.04
40	"	333.98	-0.01	77.15	-0.07	596.20	-4.31	30.39	+0.10	.036278	-.000017	333.98	0.00	77.12	-0.03
50	"	393.00	0.00	81.65	-0.05	838.22	-1.64	31.96	+0.01	.034432	-.000010	393.00	0.00	81.63	-0.02
30	"	369.62	-0.13	85.50	+0.50	955.97	-0.58	36.31	-1.07	.029344	+.000735	369.55	-0.07	85.75	+0.25
50	"	474.00	0.00	91.94	+0.46	1462.58	+3.23	38.64	-0.11	.028524	+.000016	474.00	0.00	92.17	+0.23
94	"	423.00	0.00	92.03	+0.38	1213.85	+1.98	46.69	-0.04	.025473	+.000033	423.00	0.00	92.22	+0.19
0	"	372.00	0.00	96.27	-0.08	1190.64	-1.34	53.59	-0.03	.022388	+.000013	372.00	0.00	96.23	-0.04
20	"	371.00	0.00	97.52	-0.13	1192.38	-1.09	55.65	-0.15	.022272	+.000067	371.00	0.00	97.46	-0.06
30	"	419.00	0.00	94.31	-0.01	1201.40	+0.20	57.46	-0.02	.021931	+.000004	419.00	0.00	94.30	-0.01
40	"	424.00	0.00	94.21	-0.01	1194.05	-0.85	57.66	+0.01	.022198	.000000	424.00	0.00	94.20	-0.01
40	"	372.00	0.00	104.83	-0.02	1442.47	-1.08	77.14	+0.01	.022400	.000000	372.00	0.00	104.82	-0.01
30	"	404.00	0.00	113.10	+0.02	1998.95	-0.15	55.89	+0.01	.022546	-.000008	404.00	0.00	113.11	+0.01
.37	-0.14	402.14	+0.38	91.12	-0.13	1565.97	-6.26	56.34	+0.01	.023150	+.000022	402.33	+0.19	91.06	-0.06

CALCULATIONS BY CLINTON H. HAVILL
LIEUT., U.S. NAVY.

TABLE VI

PRELIMINARY CALCULATIONS

FIGURES ON THIS SHEET ARE ONLY APPROXIMATE.

ITEM	H.P.$_{MAX.}$ 8TH APPROX.	K (PROP. COEFF) 8TH APP.	C (DRAG COEFF) 8TH APPROX.	E (PROP. EFF) 8TH APP.	A_P AREA OF DRAG POWER ON SQ. FT. 8TH APP.	$V_{MAX.}$ FT./SEC 9TH APP.	ΔV_{MAX} $(V_9 - V_8)$ FT./SEC.	H.P.$_{MAX.}$ 9TH APPROX.	ΔH.P. $HP_9 - HP_8$	K (PROP. COEFF) 9TH APP.	ΔK $K_9 - K_8$	C (DRAG COEFF) 9TH APPROX.	ΔC $(C_9 - C_8)$
1	99.73	27.40	.045591	.622	87.40	69.00	0.00	99.59	-0.14	27.51	+0.11	.045586	-.000005
2	298.22	31.54	.040031	.631	127.40	88.00	0.00	297.33	-0.89	31.56	+0.02	.039962	-.000069
3	250.00	32.94	.039595	.650	132.75	83.68	-0.57	250.00	0.00	32.86	-0.08	.039699	+.000104
4	151.55	32.94	.037582	.610	78.00	82.20	0.00	152.33	+0.78	32.75	-0.19	.037572	-.000010
5	125.90	32.95	.037673	.620	78.75	77.30	0.00	126.35	+0.45	32.81	-0.14	.037809	+.000136
6	959.45	68.07	.019583	.660	168.25	120.02	-0.03	959.17	-0.28	67.41	-0.66	.019680	+.000097
7	2023.50	63.75	.018213	.580	358.50	115.00	0.00	2020.25	-3.25	63.88	+0.13	.018169	-.000044
8	28.32	15.48	.046466	.360	252.01	26.40	0.00	27.98	-0.34	15.53	+0.05	.046350	-.000116
9	201.45	10.19	.054990	.280	390.00	41.00	0.00	202.18	+0.73	10.13	-0.06	.055285	+.000295
10	351.67	14.28	.046232	.330	374.00	52.13	-0.12	347.50	-4.17	14.32	+0.04	.046097	-.000135
11	448.96	18.42	.071435	.678	563.00	62.40	0.00	448.43	-0.53	18.43	+0.01	.071403	-.000032
12	489.45	23.27	.050995	.570	412.00	67.62	-0.13	484.17	-5.28	23.81	+0.64	.050592	-.000403
13	561.35	18.14	.057324	.520	482.00	66.77	-0.08	577.03	+15.68	18.27	+0.13	.056935	-.000389
14	611.36	23.00	.045549	.530	409.00	71.05	-0.15	602.03	-9.33	23.20	+0.20	.045423	-.000126
15	608.67	30.09	.036330	.540	353.99	77.22	-0.13	600.51	-8.61	30.29	+0.20	.036295	-.000035
16	843.24	31.93	.034467	.550	393.00	81.70	-0.10	839.86	-3.38	31.95	+0.02	.034442	-.000020
17	957.70	39.52	.027139	.530	369.75	85.00	+1.00	956.55	-1.15	37.38	-2.14	.028609	+.001470
18	1452.90	38.97	.028472	.550	474.00	91.48	+0.93	1459.35	+6.45	38.75	-0.22	.028508	+.000036
19	1207.90	4[illegible].82	.025386	.574	423.00	91.65	+0.95	1211.85	+3.95	46.73	-0.09	.025440	+.000066
20	1194.65	53.68	.022390	.600	372.00	96.35	-0.15	1191.98	-2.67	56.32	-0.06	.022375	+.000025
21	1195.65	56.10	.022070	.620	371.00	97.65	-0.25	1193.47	-2.18	55.80	-0.30	.022205	+.000135
22	1200.80	57.52	.021918	.630	419.00	94.32	-0.03	1201.20	+0.40	57.48	-0.04	.021927	+.000009
23	1196.60	57.63	.022199	.640	424.00	94.22	-0.03	1194.90	-1.70	57.65	+0.02	.022198	-.000001
24	1445.70	57.12	.022400	.640	372.00	104.85	-0.05	1443.55	-2.15	57.13	+0.01	.022400	.000000
25	1999.40	57.89	.022569	.630	404.00	113.08	+0.03	1999.10	-0.30	55.88	+0.03	.022554	-.000015
26	1584.75	36.32	.023085	.453	401.76	91.25	-0.25	1572.23	-12.52	36.33	+0.01	.023128	+.000043

AL ES	$A + A_F = \frac{2V_M}{S}$; $S_1 = \frac{2V_M}{A+A_F}$ (FT)	$S_{F1} = \frac{2V_M}{A_{F1}}$ (FT)	$S - S_F = \Delta S$ DUE TO DRAG OF STOPPED PROPS (FT)	$\frac{\Delta S}{N^o\ ENG}$ = ΔS PER ENG	AV ΔS × Nº ENGS 129 × Nº ENG	$S_1 + \Delta S_1 = S_{F2}$	$S_F - \Delta S_1 = S_2$	$\frac{S_1 + S_2}{2} = S_3$	$\frac{S_{F1} + S_{F2}}{2} = S_{F3}$	AREA OF DRAG $A_S = \frac{2V_M}{S_3}$ SQ FT	AREA OF DRAG $A_{FS} = \frac{2V_M}{S_{F3}}$ SQ FT	AREA OF DRAG AVG. POWER OFF A	AREA OF DRAG AVG. POWER ON A_F	AT CROSS POINTS (COMP. PLOT)	AREA OF DRAG A_F POWER ON 7TH APP	AREA OF DRAG A POWER OFF 7TH APP	O WAY ... 8TH APPROX
80	1931	2068	137	137	12.7	2060	1931	1934	2064	93.4	87.4	93.4	87.4	87	87.4	9[illegible]	67.00
10	2810	2961	151	15.5	258	3068	2703	2786	2984	136	127	138	127.4		127.4	14[illegible]	88.[illegible]
10	2790	3047	257	128.5	258	3048	2789	2799	3047	148	135	145	133	130	131.5	[illegible]	84.0[illegible]
20	2360	2540	180	180	129	2489	2411	2385	2514	83.6	79.6	84	78		78	84.7	82.20
20	2380	2560	180	180	129	2509	2431	2405	2534	83.1	79.9	83.5	78.7		79	85.5	77.30
20	8700	9840	1140	285	516	9216	9324	9012	9528	184	174	187	170		170	200	120.05
61	14700	15900	1200	250	645	15345	15255	14977	15622	383	366	387	363	353	357	389	115.00
10	3070	3220	150	75	258	3328	2962	3016	3274	272	249	268	251		251	268	26.40
00	3000	3100	100	50	258	3258	2842	2921	3179	398	292	392	383		383	397	4[illegible].00
70	3762	3941	179	59.6	377	4139	3564	3663	4040	407	370	401	374		374	394	52.25
30	1887	2280	393	131	377	2264	1903	1900	2272	676	566	679	567	565	563	585	62.40
10	3580	3660	120	40	377	3957	3283	3431	3808	446	399	445	412		412	433	67.75
10	3199	3241	42	14	377	3576	2864	3031	3408	528	470	520	482		482	507	66.89
10	4050	4220	170	56.7	377	4427	3343	3946	4323	442	404	437	409		409	430	71.20
40	5110	5390	280	93	377	5487	5013	5112	5436	353	332	353	334		334	353	77.35
00	5960	6360	400	100	516	6476	5844	5952	6418	420	391	419	393		393	419	81.80
00	8660	9360	700	175	516	9176	8844	8752	9268	[illegible]18	[illegible]	38[illegible]	369		370	399	84.00
20	8660	9360	700	116.6	774	8434	8[illegible]36	8623	8897	513	496	51[illegible]	48[illegible]	464	474	512	90.5
20	9760	10040	280	56	645	10405	9395	9577	10222	451	431	451	426	420	423	455	[illegible]10
20	11100	11910	810	162	645	11745	1[illegible]265	11182	11827	393	373	397	372		372	403	96.[illegible]
20	11240	12210	970	195	645	11885	11565	11402	1154[illegible]	386	361	387	371		371	403	97.9[illegible]
20	12200	12900	700	140	645	12845	12255	12227	12872	44[illegible]	420	44[illegible]	417	418	4[illegible]	452	94.[illegible]
20	11920	12710	790	158	645	12565	12065	11992	12637	451	427	453	423	425	424	457	94.25
20	11200	11820	620	124	645	11845	11175	11187	118[illegible]2	397	372	399	37[illegible]		[illegible]72	405	104.[illegible]
20	11610	12300	690	138	645	12[illegible]	11[illegible]	11632	122[illegible]	414	407	424	403	40[illegible]	404	435	[illegible]3.05
81	10920	1[illegible]720	800	160	645	11565	11075	10992	1164[illegible]	428	4[illegible]	430	[illegible]	40[illegible]	401	4[illegible]	91.50
	POWER OFF	POWER ON				POWER ON	POWER OFF	POWER OFF	POWER ON	POWER OFF	POWER ON						

CALCULATIONS BY CLINTON H. HAV[illegible]
L[illegible], U.S. NAVY.

AL ... E	A + Ar = 2 Vm / S; S₁ = 2 Vm / A + Ar (FT)	Sr₁ = 2 Vm / Ar₁ (FT)	S - Sr = ΔS Due to Drag or Stopping Propellers (FT)	ΔS / No. Eng. = ΔS per Eng.	Av ΔS × No. Engs (129 × No. Eng)	S₁ + ΔS₁ = Sr₂	Sr - ΔS₁ = S₂	(S₁ + S₂)/2 = S₃	(Sr₁ + Sr₂)/2 = Sr₃	Area of Drag As = 2 Vm / S₃ (Sq Ft)	Area of Drag Ars = 2 Vm / Sr₃ (Sq Ft)	Area of Drag Avg. Power Off A	Area of Drag Avg. Power ... Ar	A Check Points (Comp. Flt.)	Area of Drag Ar Power On 7th App.	Area of Drag A Power Off 7th App.	C max. For ... 8th (Approx.)
80	1931	2068	137	137	127	2060	1931	1934	2064	93.4	87.4	93.4	87.4	87	87.4	9[illegible]	67.00
10	2810	2961	151	15.5	258	3068	2703	2786	2984	136	127	138	127.4		127.4	14[illegible]	88.00
10	2790	3047	257	128.5	258	3048	2789	2799	3047	148	135	145	133	130	131.5	[illegible]	84.0[illegible]
20	2360	2540	180	180	129	2489	2411	2385	2514	83.6	79.6	84	78		78	84.7	82.20
20	2380	2560	180	180	129	2509	2431	2405	2534	83.1	79.9	83.5	78.7		79	85.5	77.30
20	8700	9840	1140	285	516	9216	9324	9012	9528	184	174	187	170		170	200	120.05
61	14700	15900	1200	250	645	15345	15255	14977	15622	383	366	387	363	353	357	389	115.00
10	3070	3220	150	75	258	3328	2962	3016	3274	272	249	268	251		251	268	26.40
00	3000	3100	100	50	258	3258	2842	2921	3179	398	292	392	383		383	397	4[illegible].00
70	3762	3941	179	59.6	377	4139	3564	3663	4040	407	370	401	374		374	394	52.25
30	1887	2280	393	131	377	2264	1903	1900	2272	676	566	679	567	565	563	585	62.40
10	3580	3660	120	40	377	3957	3283	3431	3808	446	399	445	412		412	433	67.75
10	3199	3241	42	14	377	3576	2864	3031	3408	528	470	520	482		482	507	66.85
10	4050	4220	170	56.7	377	4427	3343	3946	4323	442	404	437	409		409	430	71.20
40	5110	5390	280	93	377	5487	5013	5112	5436	353	332	353	334		334	353	77.35
00	5960	6360	400	100	516	6476	5844	5952	6418	420	391	419	393		393	419	81.80
00	8660	9360	700	175	516	9176	8844	8752	9268	[illegible]18	[illegible]	38[illegible]	369		370	399	84.00
20	8660	9360	700	116.6	774	8434	8[illegible]36	8623	8897	513	496	5[illegible]	48[illegible]	464	474	512	90.[illegible]
20	9760	10040	280	56	645	10405	9395	9577	10222	451	431	451	426	420	423	455	[illegible] 10
20	11100	11910	810	162	645	11745	[illegible]265	11182	11827	393	373	397	372		372	403	96.[illegible]
20	11240	12210	970	195	645	11885	11565	11402	11547	386	361	387	371		371	403	97.9[illegible]
20	12200	12900	700	140	645	12845	12255	12227	12872	44[illegible]	420	44[illegible]	417	418	4[illegible]	452	94.[illegible]
20	11920	12710	790	158	645	12565	12065	11992	12637	451	427	453	423	425	424	457	94.25
20	11200	11820	620	124	645	11845	11175	11187	118[illegible]2	397	372	399	372		[illegible]72	405	104.[illegible]
20	11610	12300	690	138	645	12[illegible]	11[illegible]	11632	122[illegible]	414	407	424	403	405	404	435	[illegible]3.05
81	10920	[illegible]720	800	160	645	11565	11075	10992	11642	428	4[illegible]	430	[illegible]	401	401	434	91.50
	Power Off	Power On				Power On	Power Off	Power Off	Power On	Power Off	Power On						

Calculations by Clinton H. Ha[illegible]

L[illegible], U. S. Navy.

$(v)^3$ $\frac{P_o \eta 550}{K \rho (\text{cal})}$ η .62	v' Ft. Sec. η .62 2ND APP.	v_{cal} (Pop.) Ft. Sec.	K''' Approx. Drag Coeff.	η Approx. Prop. Eff. (Appendix B)	v'' Ft. Sec. 3RD APP.	H.P.' P_o Full Rated H.P. Reported	$(v'')^3$ $\frac{P_o \eta 550}{K'' \rho (\text{cal})}$	v''' Ft. Sec. 4TH APP.	H.P.'' 4TH APP.	v'''_{max} Ft. Sec. 4TH APP.	K'''' 4TH APP.	η'''' 4TH APP.	K^v C_{Approx} 5TH APP.	H.P.^{v} 5TH APP.	v^v Ft. Sec. 5TH APP.
374000	68.4	69.0	.0232	.62	69.0	100	374000	68.9	100	69.0	.02785	.62	.0457	100	69.0
422000	75.1	88.0	.0280	.67	80.5	300	523000	80.6	300	80.6	.0280	.67	0560	300	88.0
376000	72.2	85.1	.0279	.67	75.1	250	422000	75.1	250	75.1	.02[illegible]	.67	0554	250	85.1
422000	75.1	82.2	0236	.64	76.8	150	452000	76.8	150	76.8	.0736	.64	0412	150	82.2
298000	66.9	77.3	.0246	.62	709	125	352000	70.6	125	709	.0246	.62	.0492	125	77.3
974000	99.2	121.5	.0172	.68	107.4	980	1270000	107.8	980	107.8	0.[illegible]	.68	0200	960	121.0
887000	96.3	110.0	.0165	69	105.1	2050	1015000	100.2	2050	105.1	.0166	.69	0180	2030	115.0
16400	25.7	26.4	.0405	60	26.2	29	18400	26.3	29	26.3	.0405	.59	0462	29	26.4
504000	79.1	41.0	.0419	.58	43.0	170	79600	431	170	43.1	.0406	.58	0460	200	41.0
924000	91.3	52.5	.0490	.60	52.5	360	126000	50.1	360	50.1	.0492	.60	0450	360	52.5
177000	562	62.3	.0690	.67	62.3	444	133000	51.1	475	51.5	0690	.67	.0715	450	67.4
208200	59.1	67.9	.0440	.65	65.0	510	213200	59.9	520	61.7	.0410	.65	.0430	500	67.9
301800	67.1	67.0	.0292	.62	630	530	301000	67.1	530	[illegible]	0302	.62	.0330	530	67.0
447000	76.8	71.5	.0303	.58	71.0	635	314000	680	635	68.0	03017	.58	.0310	630	71.5
323400	68.9	77.6	.0290	.62	76.0	635	342000	69.9	640	723	0290	.67	.0280	625	[illegible]
345900	73.4	82.0	.0260	.58	820	860	392000	74.0	860	75.1	0250	.60	0260	850	82.0
416000	745	82.0	.0270	59	820	960	376000	74.1	960	75.1	0260	.61	.0269	960	82.0
676000	853	88.7	.0200	.63	86.0	1440	635000	85.9	1440	87.0	0280	.63	.0274	1440	88.7
348000	70.1	88.8	.0210	57	78.0	1230	405000	74.3	1260	744	0240	.57	0312	1270	888
463000	776	96.8	0230	64	94.0	1200	467000	71.5	1260	86.0	0220	.64	.0243	1200	96.8
473000	77.9	98.4	0210	67	900	1320	588000	834	1360	84.7	0210	.67	.0232	1200	984
410100	74.2	94.4	.0220	.67	94.4	1320	502000	79.7	1360	80.1	0220	.65	0229	1200	94.4
422000	75.1	94.3	.0210	66	94.3	1320	624000	79.4	1360	81.1	0210	.68	.0222	1200	94.3
478000	78.1	105.0	.0200	.66	105.0	1460	625000	85.5	1490	92.6	.0200	67	.0224	1450	105.0
817000	931	113.2	.0700	65	113.2	2140	705000	76.8	2150	77.5	0700	.67	.0226	2000	113.0
754000	91.2	97.0	.0207	.64	97.0	1575	651000	86.7	1580	85.7	.0210	62	.0230	1610	92.0

CALCULATIONS BY CLINTON H. HAVILL
LIEUT., U.S. NAVY.

PR[illegible] CALCULATIONS

FIGURE [illegible] S[illegible] AR[illegible] ONLY APP[illegible]

ITEM	[illegible] Total Drag Due To Envel. (%)	Total [illegible] 88 Ft/sec (lbs)	To A[illegible] @ 88 Ft/sec (lbs)	[illegible] 88 Ft/sec (lbs)	K'	HP[illegible] 550 / 62	KC(Vol)^{2/3} (C .0023)	U	U max Calc / .62 Ft/sec 1st App.	[illegible] Ft/sec	[illegible] Calc − Ref Ft/sec	K'' (Assum[illegible] Where Possible)	[illegible] X K/K	K'(vol)
1	37.1	7.98	7[illegible]8	502	[illegible].428	[illegible]4100	.0648	526000	80.7	69.0	+11.1	.0232	1.633	.1052
2	38.4	11.56	[illegible]58	713	[illegible]	102300	.1495	686000	88.2	88.0	0.2	.0322	1.633	.2430
3	43.2	10.72	1072	608	.01770	85250	.138[illegible]	614000	85.0	85.1	0.1	.0289	1.633	.2262
4	69.5	5.76	576	176	.01510	51150	[illegible]	686000	88.2	82.2	+ 6.0	.0246	1.633	.1216
5	58.3	6.87	687	287	.01110	42600	.0816	486000	78.6	77.3	+ 1.3	.0289	1.633	.1430
6	92.06	14.3	1430	120	.00910	321360	.1849	1736000	120.1	121.5	− 1.4	.0149	1.633	.3300
7	69.5	37.9	3790	1120	.01030	682000	.489	1345000	111.9	110.0	+ 1.9	.0165	1.570	.7690
8	19.6	34.1	3410	2742	.03420	9880	.441	22380	28.1	26.4	+ 1.7	.0468	1.372	.6020
9	12.0	76.6	7660	6740	.06075	68200	.991	68800	41.1	41.0	− 0.1	.0834	1.372	1.3520
10	14.1	74.4	7440	6381	.04970	12280	.958	128200	50.7	52.5	− 1.8	.0640	1.372	1.3300
11	21.2	48.4	4840	3818	.03342	151200	.624	243000	62.8	62.3	+ 0.5	.0459	1.374	.8560
12	24.1	45.3	4530	3440	.03018	168000	.587	286200	65.9	67.9	− 2.0	.0414	1.374	.8060
13	36.5	32.1	3210	2040	.02063	177900	.483	367900	71.5	67.0	+ 4.5	.0292	1.374	.5900
14	24.1	48.4	4840	3647	.01928	214200	.626	343000	70.0	71.5	− 1.5	.0403	1.374	.8610
15	36.7	36.7	3670	2368	.02180	212000	.477	444000	76.2	77.6	− 1.4	.0300	1.374	.6555
16	37.6	40.7	4070	2540	.01960	289000	[illegible]	562000	82.4	82.0	+ 0.4	.0267	1.374	.7230
17	37.8	44.2	4420	2750	.01959	327000	.568	576000	83.2	82.0	+ 1.2	.0270	1.376	.7860
18	41.9	54.8	5480	3192	.01799	471040	.708	675000	88.8	88.7	− 0.1	.0200	1.120	.7880
19	50.6	45.0	4500	2220	.01482	409700	.583	703000	88.9	88.8	+ 0.1	.0249	2.021	1.1780
20	65.8	34.7	3470	11[illegible]	.01135	409200	.426	964000	97.1	96.8	+ 0.3	.0226	2.071	.8800
21	68.5	33.3	3330	10[illegible]	.01088	409700	.427	957000	98.3	98.4	− 0.1	.0220	2.021	.8650
22	66.7	37.6	3760	17[illegible]	.0107[illegible]	409700	.487	839000	94.1	94.4	− 0.3	.0220	2.030	.9960
23	66.1	37.[illegible]	3790	1288	.0106[illegible]	409200	.490	834900	94.1	94.3	− 0.2	.0210	1.940	.9520
24	69.0	33.1	3310	1030	.01082	494250	.426	861000	95.2	105.0	− 9.8	.0217	2.030	.8550
25	61.1	41.8	4180	1620	.01262	692730	.536	1271000	108.8	113.2	− 4.4	.0200	1.582	.8480
26	57.6	41.6	4160	1762	.01310	646500	.532	1204000	106.7	97.0	+ 9.4	.0207	1.580	.8510
			K_{sp}	K_{sp} (Vol)	$K_{sp} \cdot C (vol)^{2/3}$ = .00237 U, 88									

S.F. @ 88 Ft/Sec (Lbs) $.03385A_s^{.83}$	.001662 Emp. Const for Effect 1st Approx.	.0000476 $\lambda \times \frac{V}{AL}^x \times \frac{L}{D}$ 1st Approx.	Approximate Drag Coefficient Due To Pressure Diff. K_p	Skin Friction K_s	Hull K	% Drag Due To S.F. (%)	Drag of Hull At 88 Ft/Sec (Lbs)	Max. Vel. Reported Ft/Sec (v)	v^2	Drag At Rep. v Max. Lbs (Hull Only)	Thrust = HP × .62 (.62 Assumed)	Thrust At Rep v Max $\frac{.62 HP 550}{v \text{ Max}}$	Drag Due To Cars, Fins Etc (Lbs)	% Total Drag Due To Cars Etc %
.242	.00158	-.0001055	.001475	.00693	.008405	82.4	296	69.0	4761	184	62	495	311	62.9
361	.00155	-.0001360	.001414	.00618	.007594	81.6	445	88.0	7774	445	186	1161	716	61.6
380	.00155	-.0001616	.001388	.00625	.007638	81.9	464	85.1	7242	432	155	1002	570	56.8
345	.00159	-.0001473	.001453	.00903	.010483	86.2	400	88.2	7779	403	93	580	177	30.5
345	.00159	-.0001473	.001453	.00903	.010483	86.2	400	77.3	5975	309	77.5	551	242	41.7
1086	.00161	-.0001920	.001418	.00689	.008308	82.8	1310	121.5	14762	2495	595.2	2710	215	7.94
2162	.00162	-.0002190	.001401	.00601	.007411	81.2	2670	110.0	12100	4170	1240	6200	2030	30.5
694	.00161	-.0003421	.001268	.00698	.008248	84.7	668	26.4	697	73.8	18	374	300	80.4
768	.00163	-.0004380	.001192	.00608	.007272	83.6	920	41.0	1681	199.5	124	1662	1462	88.0
884	.00163	-.0004640	.001164	.00593	.007094	83.7	1059	52.5	2756	376	223.2	2340	1964	83.9
844	.00162	-.0003870	.001243	.00583	.007073	82.6	1022	62.3	3881	514	275.3	2430	1916	78.8
905	.00162	-.0003860	.001234	.00601	.007244	83.1	1090	67.9	4610	650	306.9	2490	1840	73.9
978	.00162	-.0004020	.001218	.00626	.007478	83.7	1170	67.0	4489	677	325	1850	1173	63.5
999	.00161	-.0004380	.001182	.00604	.007222	83.7	1198	71.5	5112	740	390	3000	2260	75.3
1089	.00160	-.0003590	.001241	.00643	.007671	83.8	1322	77.6	6022	1010	385.6	2730	1720	63.1
1262	.00159	-.0003022	.001288	.00603	.007318	82.4	1530	82.0	6724	1332	527	3540	2208	62.4
1388	.00159	-.0003342	.001256	.00616	.007416	83.2	1670	82.0	6724	1510	595.2	3980	2470	62.2
1866	.00162	-.0002640	.001356	.00612	.007476	81.9	2288	88.7	7867	2320	892.8	5530	3210	58.1
1870	.00162	-.0002621	.001358	.00613	.007488	82.0	2280	88.8	7885	2324	744	4600	2276	49.4
1870	.00162	-.0002621	.001358	.00613	.007488	82.0	2280	96.8	9370	2781	744	4230	1449	34.2
1872	.00162	-.0002624	.001358	.00612	.007478	81.9	2280	98.4	9682	2850	744	4160	1310	31.5
2036	.00162	.0002800	.001340	.00580	.007140	81.3	2502	94.4	8911	2890	744	4330	1440	33.3
2036	.00162	-.0002800	.001340	.00580	.007140	81.3	2502	94.3	8892	2870	744	4340	1470	33.9
1870	.00162	-.0002621	.001358	.00613	.007488	81.7	2280	105.0	11025	3242	899	4700	1458	31.0
2124	.00162	-.0003038	.001316	.00646	.007776	82.9	2560	113.2	12814	3740	1258.6	6170	2380	38.9
1970	.00162	.0002779	.001342	.00619	.007532	82.2	2398	97.0	9409	3040	930	5280	2240	42.4
$.03385A_s^{.83}$	.00166 λ		Approaches True Coeff.				$K\rho v^2 (V)^{2/3}$ $\rho = .00237$			$K\rho v^2 (V)^{2/3}$ $\rho = .00237$			At v Max. Approx.	

Calculations by Clinton H. Havill
Lieut., U.S. Navy.

TABLE III

PRELIMINARY CALCULATIONS

FIGURES ON THIS SHEET ARE ONLY APPROXIMATE.

ITEM	ECC × CYL COEFF.	% OF HULL DRAG DUE TO SKIN FRICTION (APPROXIMATE) (EMPIRICAL)	ECC. × CYL COEF × $\frac{L}{D}$	DRAG COEF DUE TO S. F (1ST APPROX.)	$\sqrt{VL}$ (SQ. FT)	TOTAL SURFACE AREA (SQ. FT)	$\frac{V}{D}$ (SQ FT)	$594\sqrt{VL}$	$-3.49\frac{V}{D}$	$A_S^{.93}$	$88^{1.86}$ (60 M/H = 88 FT/SEC)	$.00008193 \times 88^{1.86}$
1	.458	.58675	2.21	.00446	3700.4	13950	2301	21980	− 8030	7152	4137.4	.03385
2	.621	.56629	2.86	.00430	5939.7	21424	4286	35382	− 14958	10660	"	"
3	.647	.56481	3.40	.00429	6133.6	23061	4524	36434	− 15788	11415	"	"
4	.637	.58362	3.10	.00443	3923.0	20404	2836	23303	− 9898	10187	"	"
5	.637	.58362	3.10	.00443	3923.0	20404	2836	23303	− 9898	10187	"	"
6	.604	.52800	4.04	.00401	18448.0	69990	11427	109800	− 39810	32055	"	"
7	.636	.48669	4.61	.00371	42660.0	147027	30483	253413	−106386	63915	"	"
8	.705	.54538	7.20	.00414	13084	41100	10471	77610	− 36510	20459	4137.4	.03385
9	.879	.53629	9.21	.00408	15973	48180	13396	98430	− 46650	22650	"	"
10	.901	.53004	9.76	.00403	18888	56300	15991	112100	− 55800	26180	"	"
11	.814	.53385	8.14	.00406	17037	53400	13748	101300	− 47900	24924	"	"
12	.839	.52971	8.12	.00402	18620	57600	15246	110800	− 53200	26742	"	"
13	.807	.52831	8.45	.00402	20084	62650	16127	119000	− 56350	28916	"	"
14	.870	.52625	9.21	.00400	21103	64000	17681	125300	− 61300	29495	"	"
15	.749	.52447	7.55	.00399	21645	70300	16806	128900	− 58600	32186	"	"
16	.734	.51745	6.36	.00393	25572	82400	19741	151300	− 68900	37309	"	"
17	.741	.51485	7.05	.00391	28262	91000	22059	167900	− 76900	40916	"	"
18	.674	.50394	5.55	.00383	37230	125200	27446	221000	− 95800	55051	"	"
19	.671	.50401	5.52	.00383	37148	125430	27331	220736	− 95200	55149	"	"
20	.671	.50401	5.52	.00383	37148	125436	27331	220736	− 95200	55149	"	"
21	.672	.50400	5.53	.00383	37161	125500	27344	220800	− 95300	55174	"	"
22	.619	.47910	5.89	.00379	44349	146200	33716	263800	−117600	61010	"	"
23	.619	.49910	5.84	.00379	44349	146200	33716	263800	−117600	61010	"	"
24	.672	.50400	5.53	.00383	37161	125436	27344	220736	− 95300	55149	"	"
25	.671	.50134	6.38	.00381	42269	144173	30651	261173	−107000	62784	"	"
26	.676	.50244	5.84	.00382	39465	132889	29096	234422	−101535	58187	"	"
	$\frac{V}{A_L}$	$V^{.047}$		$.0076\,V^{-.047}$	$\sqrt{VL}$	A_S	$\frac{V}{D}$	$5.94\sqrt{VL}$	$-3.49\frac{V}{D}$	$A_S^{.93}$	$88^{1.86}$	

$\left(\text{Air Volume}\right)^{\frac{2}{3}}$ Sq. Ft.	No. Eng's	No. Gas Cells	Fine-ness Ratio	Max Cross Section Area Sq. Ft.	Volume of Circ. Cylinder Cu. Ft.	Cyl. Coeff.	Distance from Nose to Max. Ord. % L	Ft. (x)	Max. Radius Ft. (r)	x^2	r^2	x^2-r^2	$\sqrt{x^2-r^2}$	Ecc. of Nose Ellipse ε
1918	1	N.R.	4.46	1046	170900	.482	37.00	60.4	18.25	3648.16	333.06	3315.1	57.58	.954
3188	2	N.R	4.62	1385	271900	.664	30.00	58.8	21.00	3457.44	441.00	3016.4	54.91	.935
3305	2	N.R	4.72	1385	274100	.693	29.70	58.8	21.00	3457.44	441.00	3016.4	54.91	.935
2082	1	N.R	4.84	881	142500	.667	36.25	58.7	16.75	3445.64	280.56	3165.3	56.27	.956
2082	1	N.R	4.84	881	142500	.667	36.25	58.7	16.75	3445.64	280.56	3165.3	56.27	.956
8596	4		6.70	2999	1280000	.672	30.75	131.2	30.90	17213.44	954.81	16258.6	127.61	.972
19697	5	14	7.25	6461	4253276	.650	38.50	236.2	45.35	55790.44	2068.62	53721.8	231.78	.978
5429	2	17	10.21	1146	552000	.726	17.50	75.2	18.10	5655.04	327.61	5327.4	72.99	.971
6891	2	18	10.50	1432	639900	.893	25.80	114.8	21.35	13179.04	455.82	12723.2	112.99	.984
8137	3	18	10.60	1655	804000	.914	23.62	114.8	22.95	13179.04	526.70	12652.3	112.81	.983
7888	3	17	10.00	1655	761300	.829	25.00	114.8	22.95	13179.04	526.70	12652.3	112.81	.983
8209	3	16	9.55	1870	870000	.856	24.61	114.8	24.40	13179.04	595.36	12583.7	112.29	.979
8524	3	18	10.48	1870	956000	.823	22.40	114.8	24.40	13179.04	595.36	12583.7	112.29	.979
9029	3	18	10.61	1870	969000	.886	22.19	114.8	24.40	13179.04	595.36	12583.7	112.29	.980
9211	3	15	10.08	2173	1148000	.770	21.62	114.8	26.30	13179.04	691.69	12487.4	111.63	.972
11417	4	16	8.68	2999	1600000	.762	21.40	114.8	30.90	13179.04	954.81	12224.2	110.44	.963
12284	4	18	9.50	2999	1750000	.770	19.62	114.8	30.90	13179.04	954.81	12224.2	110.44	.963
16652	6	19	8.24	4815	3105797	.691	30.80	180.5	39.15	32580.25	1532.72	31047.5	176.10	.976
16606	5	18	8.24	4815	3105797	.688	30.80	180.5	39.15	32580.25	1532.72	31047.5	176.10	.976
16606	5	18	8.24	4815	3105797	.688	30.80	180.5	39.15	32580.25	1532.72	31047.5	176.10	.976
16607	5	14	8.24	4815	3105797	.689	30.80	180.5	39.15	32580.25	1532.72	31047.5	176.10	.976
19101	5	16	9.52	4815	3587316	.737	24.40	180.5	39.15	32580.25	1532.72	31047.5	176.10	.976
19101	5	16	9.52	4815	3587316	.737	24.40	180.5	39.15	32580.25	1532.72	31047.5	176.10	.976
16607	5	14	8.24	4815	3105797	.689	30.80	180.5	39.15	32580.25	1532.72	31047.5	176.10	.976
17925	5	15	9.52	4815	3587316	.688	24.40	180.5	39.15	32580.25	1532.72	31047.5	176.10	.976
17372	5	20	8.64	4864	3308492	.694	26.20	180.5	39.35	32580.25	1548.42	31031.8	176.09	.976
$V^{\frac{2}{3}}$		N.R. = Non Rigid.	$\frac{L}{D}$	A	$A \times L$	$\frac{V}{AL}$		x	$r=\frac{D}{2}$	x^2	r^2	x^2-r^2	$\sqrt{x^2-r^2}$	$\frac{\sqrt{x^2-r^2}}{x}$

Calculations by Clinton H. Havill
Lieut., U.S. Navy.

TABLE II

PRELIMINARY CALCULATIONS

FIGURES ON THIS SHEET ARE ONLY APPROXIMATE.

ITEM	SHIP BUILDERS NUMBERS	GAS VOLUME CU FT.	LENGTH FT (L)	MAX. DIAM. FT. (D)	MAX. SPEED REPORTED AV. OF DIFF. REPORTS MI/HR.	KNOTS	FT/SEC.	FULL RATED HORSE POWER	AIR VOLUME OF HULL CU. FT.
	CONTINUOUS CURVATURE SERIES								
1	U.S.N. "B"	84000	163	36.5	47	40.8	69	100	84000
2	U.S.N. "C"	180000	196	42	60	52	88	300	180000
3	U.S.N. "D"	190000	198	42	58	50.2	85.1	250	190000
4	U.S.N. "E"	95000	162	33.5	56	48.6	82.2	150	95000
5	U.S.N "F"	95000	162	33.5	52	45.1	77.3	125	95000
6	LZ-120 & 121 BODENSEE (AFTER LENGTHENING) NORDSTERN	706200	427	61.8	83	72	121.5	960	797000
7	LZ-126 U.S.S. LOS ANGELES (NO WATER RECOVERY)	2599110	658.3	90.7	75	65.1	110	2000	2764461
	PARALLEL SECTION SERIES								
8	LZ-4	375000	428	38.2	18	15.6	26.4	29	400000
9	LZ-4 & 5	530000	446	42.7	27.9	24.2	41	200	572000
10	LZ-7 & 8	680200	484	45.9	35.7	31.	52.5	360	734000
11	LZ-10 & 12	592000	460	45.9	42.5	36.8	62.3	444	631000
12	LZ-15 & 16	688000	466	48.8	46.3	40.3	67.9	495	744000
13	LZ-22 & 23	728000	512	48.8	45.6	39.6	67	525	787000
14	LZ-24 & 25 & 27 To 35	794000	519	48.8	48.7	42.7	71.5	630	85800
15	LZ-36	830000	530	52.6	53.0	46.	77.6	622	884000
16	LZ-42 To 50	1130000	536	61.8	55.9	48.6	82	850	1220000
17	LZ-59 To 61; 64 To 71 EXCEPT 60 & 70.	1262000	586	61.8	55.9	48.6	82	960	1363000
18	LZ-72 To 90 EXCEPT 73, 77 & 81.	1945000	645	78.3	60.4	52.9	88.7	1440	2149000
19	LZ-91 To 94	1965298	645	78.3	60.5	52.9	88.8	1200	2140000
20	LZ-95 To 99	1970000	645	78.3	65.9	57.2	96.8	1200	2140000
21	LZ-100 & 101	1972000	645	78.3	67.1	58.3	98.4	1200	2141000
22	LZ-102	2420000	745	78.3	64.5	55.9	94.4	1200	2640000
23	LZ-104 (CALLED L-59 AFRICAN SHIP)	2427000	745	78.3	64.4	55.9	94.3	1200	2640000
24	LZ-106 To 111	1972000	645	78.3	71.5	62.1	105.0	1450	2141000
25	LZ-112 To 114	2190000	745	78.3	77.3	67.1	113.2	2030	2400000
26	ZR-1 U.S.S. SHENANDOAH (NO WATER RECOVERY 5 ENGINES)	2151174	680.2	78.7	66.2	57.5	97.0	1500	228986
			L	D			v	HP	V

	PRINCIPAL DATA							CONSISTENT RESULTS OF PART I							
	Gas Volume Cu. Ft.	Length Ft.	Max. Diam of Hull Ft.	Air Volume of Hull Cu. Ft.	No. of [illegible]	Fineness Ratio	Total Surface Area of Hull Sq. Ft.	Maximum Speed Ft./Sec.	Mi./Hr.	Kts./Hr.	$H.P._{Max}$	K* Prop. Coeff.	F* Prop. Eff.	A_p* [illegible]	C* (Whole Ship)
	84000	183	36.5	84000	1	5.06	13750	69.00	47.04	40.86	[illegible]	27.63	.622	87.40	.045582
	180000	196	4[illegible]	180000	2	4.62	21474	88.00	60.00	52.11	296.42	31.59	.631	127.40	.037962
	190000	198	47	190000	2	4.72	23[illegible]	83.11	56.66	49.21	250.00	32.78	.650	131.49	.039801
	95000	16[illegible]	33.5	95000	1	4.84	2[illegible]	82.20	56.04	48.67	[illegible]	32.55	.610	[illegible]	.037761
	95000	162	33.5	95000	1	4.84	20400	77.30	52.70	45.11	[illegible]	32.66	.620	19.01	.037745
	706200	427	61.8	797000	4	6.70	59790	119.99	81.81	71.05	958.89	66.76	.660	170.01	.019776
[illegible]	2599110	658.3	90.7	2764461	5	7.29	141077	115.00	78.41	68.09	2017.00	64.03	.780	356.99	.018125
	379000	428	38.2	400000	2	10.21	41100	26.40	18.00	15.63	27.63	15.78	.360	251.00	.046234
	530000	446	47.7	512000	2	10.50	48180	41.00	27.95	24.28	202.93	10.08	.280	383.01	.055578
	680200	486	45.9	734000	3	10.60	5[illegible]300	51.98	35.44	30.78	343.34	[illegible]	.330	374.00	.045973
	592000	460	45.9	631000	3	10.00	53400	62.40	42.54	36.95	347.88	18.44	.658	563.00	.071371
	688000	466	48.8	734000	3	9.55	57600	[illegible]7.50	46.02	39.97	419.89	24.[illegible]	.570	412.00	.050191
	728000	512	48.8	787000	3	10.48	[illegible]	[illegible]	45.47	39.49	592.11	[illegible]8.42	.520	482.00	.054547
	794000	519	48.8	558000	3	10.61	[illegible]	[illegible].89	48.33	41.9[illegible]	592.68	23.10	.530	409.00	.054798
	8[illegible]0000	530	52.6	884000	3	10.08	703[illegible]	[illegible]	52.56	45.65	591.10	30.51	.540	333.98	.026762
LZ	1150000	536	[illegible]	1220000	4	8.68	82[illegible]	8[illegible]	55.64	48.32	836.58	31.96	.550	393.00	.054122
NAVY	1267000	586	[illegible]	1363000	4	9.50	9100[illegible]	86.00	58.64	50.97	959.39	35.25	.530	367.49	.030068
145, 170	1945000	645	78.3	2145000	6	8.24	125200	[illegible]	63.00	54.71	1465.00	38.57	.550	474.00	.028540
	1965298	645	78.3	2140000	5	8.24	125430	92.41	63.01	54.72	1215.81	[illegible]	.594	423.00	.025505
	1970000	645	78.3	2110000	5	8.24	125436	96.19	[illegible]	56.96	1189.30	53.57	.600	372.00	.02240[illegible]
	197[illegible]	645	78.3	2141000	5	8.24	125900	97.40	66.41	57.67	119[illegible].30	[illegible]	.620	371.00	.0223[illegible]0
	2420000	745	78.3	[illegible]0000	[illegible]	9.52	146200	[illegible]	64.29	55.83	120[illegible]	57.44	.630	419.00	.02[illegible]
	2471000	745	78.3	2640000	5	9.52	146200	[illegible]	64.22	55.77	1193.21	57.66	.640	424.00	.022198
	1973000	645	78.3	2141000	5	8.24	125436	104.81	71.46	62.06	1441.39	57.14	[illegible]	372.00	.022400
	2190000	745	78.3	2400000	5	9.52	144173	[illegible]	77.13	66.98	1993.81	55.91	.630	404.00	.022536
[illegible]	2151174	680.2	78.[illegible]	[illegible]59861	5	8.64	132889	[illegible]00	62.04	53.88	1559.71	36.34	.425	402.51	.023172

[illegible]

EN ONE FOR THE OTHER. THIS IS DUE TO
VY "L", AND THE GERMAN ARMY "LZ".
ETTERS.

CALCULATIONS BY CLINTON H. HAVILL
LIEUT., U. S. NAVY

[illegible] I

GENE[illegible] DATA A[illegible] [illegible] SUMMARY OF PART I

ITEM	SHIP. BUILDER'S NUMBERS.	BUILDERS	OWNERS	NAMED BY OWNERS. (SEE NOTE)
	CONTINUOUS CURVATURE SERIES.			
1	U.S.N. "B"	U.S. MFRS.	U.S. NAVY & ARMY.	U.S. NAVY "B" & U.S. ARMY "B"
2	U.S.N. "C"	"	" "	" "C" " "C"
3	U.S.N. "D"	"	" "	" "D" " "D"
4	U.S.N. "E"	"	" "	" "E" " "E"
5	U.S.N. "F"	"	" "	" "F" " "F"
6	LZ-120 & 121 BODENSEE (AFTE[illegible]) NORDSTERN.	ZEPPELIN	GERMAN [illegible] NAV. CO.	BODENSEE & NORDSTERN.
7	LZ-126 U.S.S. LOS ANGE[illegible]	"	U.S. NAVY.	U.S.S. LOS ANGELES [illegible]
	PARALLEL SECTION SERIES.			
8	LZ-1	ZEPPELIN	ZEPPELIN	LZ-1
9	LZ-4 & 5	"	& GERMAN ARMY	LZ 4 & ARMY Z II
10	LZ-7 & 8	"	GER. A[illegible] NAV. CO.	DEUTSCHLAND & ERSATZ.
11	LZ-10 & 12	"	& GER. ARMY	[illegible] & ARMY Z III
12	LZ-15 & 16	"	GERMAN ARMY.	ERSATZ Z I & ARMY Z IV
13	LZ-22 & 23	"		ARMY Z VII & Z VIII
14	LZ-24 TO 35 (EXCEPT 36)	"	& NAVY.	[illegible] 8 L8 AND ARMY Z [illegible] LZ 34 [illegible] 35.
15	LZ-36	"	NAVY	[illegible] L9
16	LZ-47 TO 50	"	" & ARMY	[illegible] LZ 72, [illegible]74 LZ77 & [illegible]79 AND NAVY [illegible]
17	LZ-59 TO 61 & 64 TO [illegible] (EXCEPT 60 & 70)	"	" "	[illegible] LZ 82, [illegible]Z 9[illegible], [illegible] & LZ 101 A[illegible] L[illegible] LZ 72, LZ 3[illegible] & [illegible]24.
18	LZ-72 TO 90 (EXCEPT 73, 77 & 81)	"	" "	[illegible] L31, L32, L21, L35, L36, L3[illegible] [illegible] L40 & L50 AND ARMY [illegible]103, LZ 113 & L[illegible]
19	LZ-91 TO 94	"	" "	NAVY L42, L43, L44 & L46.
20	LZ-95 TO 99	"	" "	L48, L49, L51, L52 & L54.
21	LZ-100 & 10[illegible]	"	" "	L53 & L55.
22	LZ-102	"	" "	L57.
23	LZ-104	"	" "	L57
24	LZ-106 TO 111	"	" "	L61, L62, L60, L64, L63 & L65.
25	LZ 117 TO 114	"	" "	L70 & L71
26	ZR-1 U.S.S. SHENANDOAH	U.S. NAVY	U.S. NAVY	U.S.S. SHENANDOAH, [illegible]

NOTE:— IN THE CASE OF GERMAN BUILT SHIPS, THE BUILDERS AND OWNER'S NUMBERS ARE APT TO BE MISTA[illegible] THE FACT THAT, THE ZEPPELIN COMPANY USES THE DESIGNATING LETTERS "LZ", THE GERMAN [illegible] HOWEVER EACH OF THE ORGANIZATIONS USES DIFFERENT NUMBERS AFTER THE DESIGNATING [illegible]

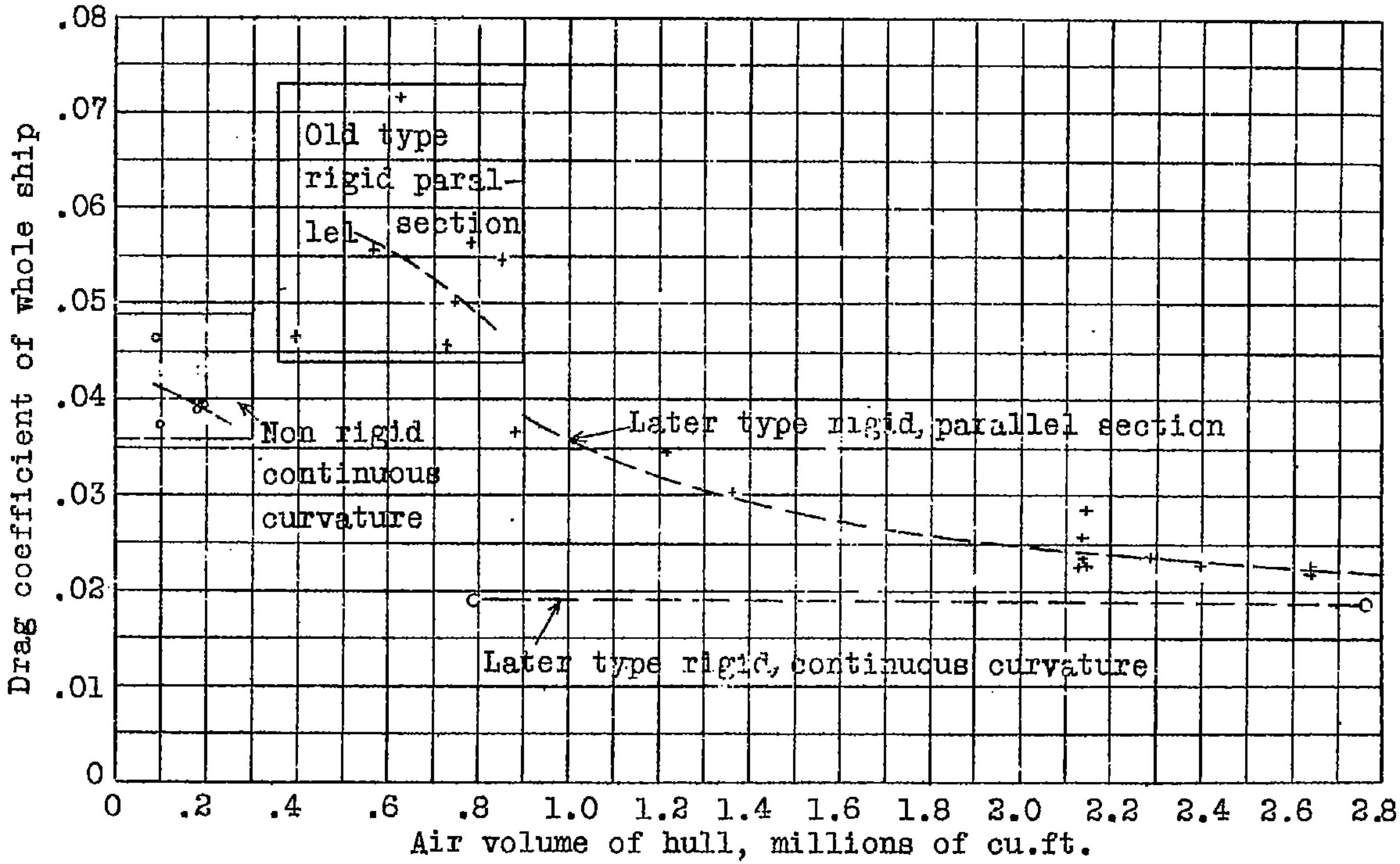

Fig.3 Plot of design history of American & German airships. Drag Coefficient of whole ship vs. air volume of hull. Data from results of part I. (Each plotted point is the plot of an item).